EXPERIMENTAL AND RESEARCH STATION

CHESHUNT, HERTS.

ANNUAL REPORT

(THIRTY-FOURTH YEAR)

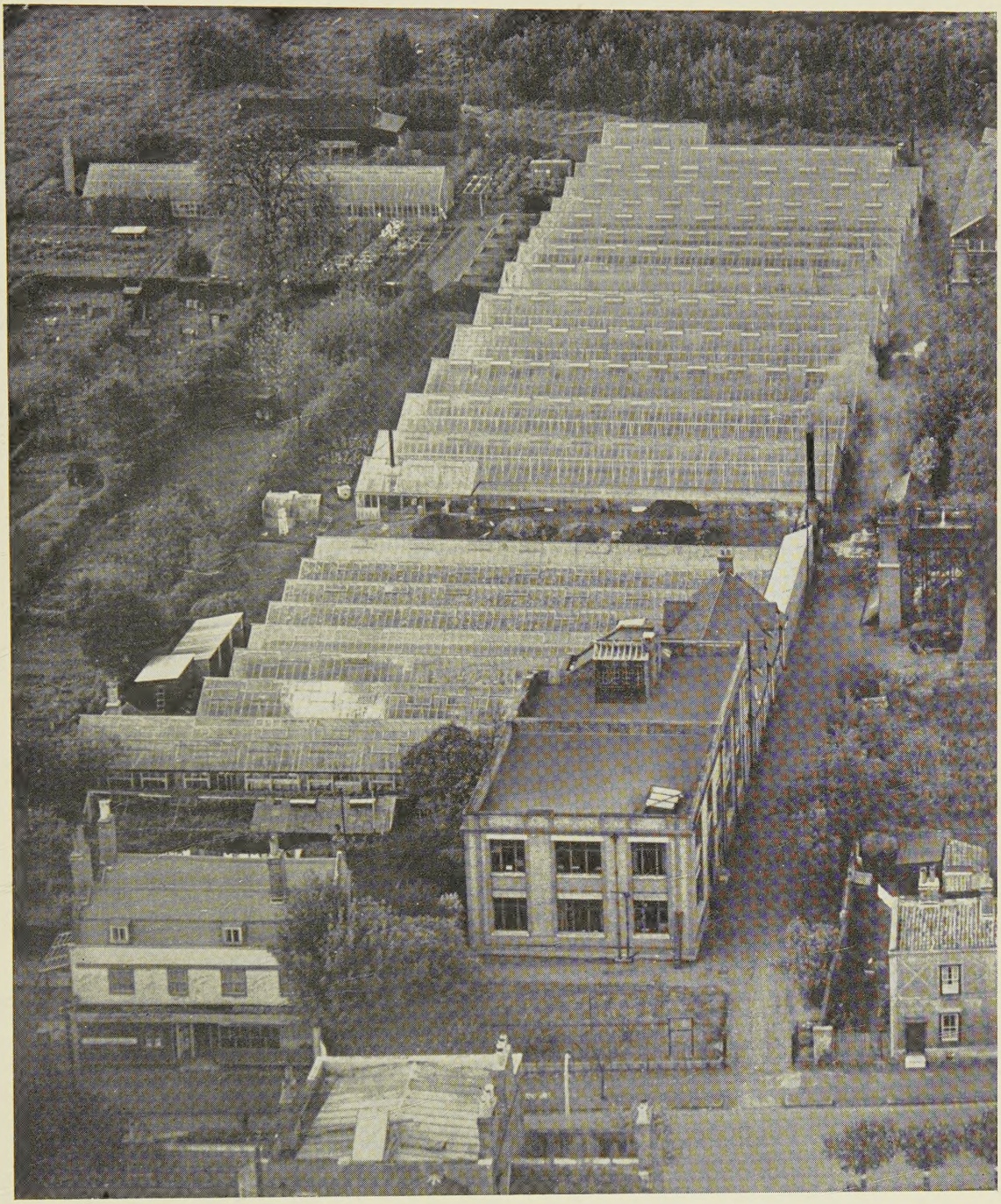
1948

NURSERY & MARKET GARDEN INDUSTRIES'
DEVELOPMENT SOCIETY, LIMITED

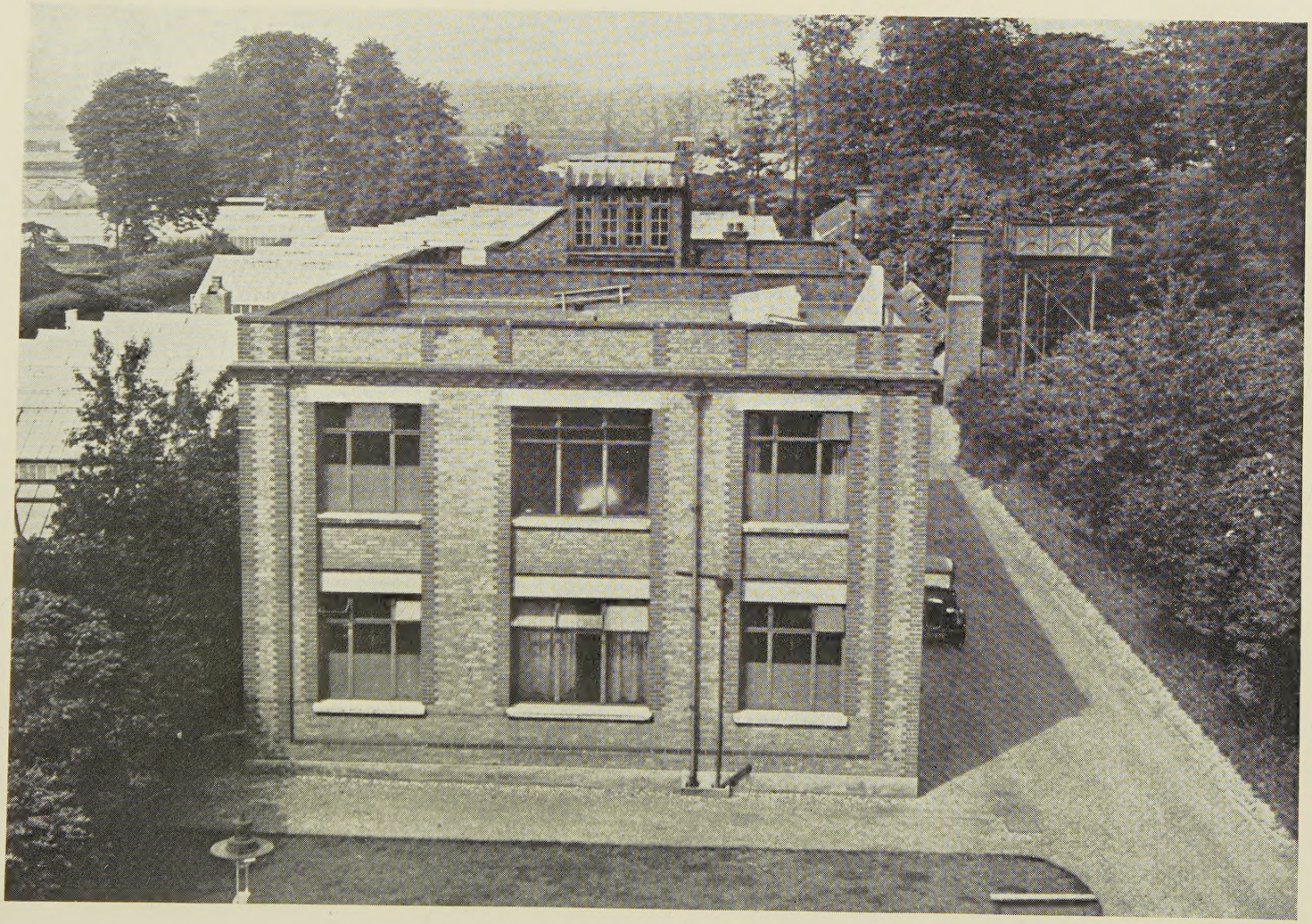
The abbreviated title of this Report as given in the World List of Scientific Periodicals is:—

Rep. Exp. Res. Sta., Cheshunt, 1948

THOMAS KNIGHT & COMPANY, LIMITED
THE CLOCK HOUSE PRESS
HODDESDON - HERTS
1949



The Research Station from the air.



The Research Station from the main road.

Nursery and Market Garden Industries' Development Society, Limited

OFFICERS 1948

President:

GEO. MONRO, Esq., C.B.E., V.M.H.

Hon. Treasurer:

A. A. POLLARD, Esq., J.P.

Committee of Management:

*Professor V. H. BLACKMAN, M.A., D.Sc., F.R.S.

E. A. BOWLES, Esq., M.A., V.M.H. (Middx. County Council)

L. MADSEN, Esq.

E. GALLOWAY, Esq.

J. R. WEBSTER, Esq.

C. J. HORWOOD, Esq.

E. STEVENS, Esq.

*Sir E. JOHN RUSSELL, O.B.E., D.Sc., F.R.S.

A. RHODES, Esq.

A. B. SWAIN, Esq. (Herts County Council)

H. V. TAYLOR, Esq., O.B.E., D.Sc., V.M.H.

†W. H. YOUNG, Esq.

Auditors:

Messrs. GEORGE COBLEY & Co.
33 Henrietta Street, Covent Garden,
W.C.2

Bankers:

MIDLAND BANK, LIMITED

Solicitors:

Messrs. HUTCHISON & CUFF,
6 Stone Buildings, Lincoln's Inn,
W.C.2

* *Nominated by the Committee of the Lawes' Agricultural Trust, Rothamsted, Harpenden, Herts.*

† *Nominated by Worthing Growers.*

Experimental and Research Station

SCIENTIFIC STAFF

Director:

W. F. Bewley, C.B.E., D.Sc. (Dunelm), V.M.H.

Entomology:

E. R. Speyer, M.A.(Oxon), F.R.E.S.
W. J. Parr
J. M. Garthwaite, B.Sc.(London)

Plant Pathology:

P. H. Williams, B.Sc.(London)	Mycology
M. Ebben, B.A.(Cantab)	,,
R. Howles, B.A., Ph.D.(Cantab)	Virology
Erna Grossbard, B.Sc.(London)	Antibiotics
J. M. Rice, B.Sc.(London)	Chemistry

Laboratory Assistants:

R. Layzell, R. Pawley, D. Underdown, A. Dyke, J. Norris

Chemistry:

O. Owen, M.Sc.(Wales), Ph.D., F.R.I.C.	General
G. W. Winsor, B.Sc.(Bristol), A.R.I.C.	,,
J. N. Davies, B.Sc.(London)	,,
J. H. Messing, B.Sc.(London)	,,
L. D. Woollard, B.Sc.(London), A.R.I.C.	,,
W. H. Read, M.Sc.(Birmingham), A.R.I.C.	Insecticides and Fungicides
R. J. Smith, B.Sc.(London)	,, ,,

Laboratory Assistants:

G. Percival, R. Melleney, J. Dyke

Director's Assistant:

J. E. Morton, A.R.P.S.

ADMINISTRATION

Secretary:

Gwendolen Dunster, B.A.(London)

Assistants:

Joyce M. Masson, Audrey M. Lowin and Jean P. Westerman

NURSERY STAFF

Nursery Manager and Demonstrator: A. A. Richards

Foreman: T. W. Syer

Assistants: F. Blake, H. B. Clifford, I. Eaton, W. H. James, A. E. Judd, H. J. Newman, G. Tyrell, G. Walpole and L. Wilkinson

Digitized by the Internet Archive
in 2025

https://archive.org/details/annual-report-glasshouse-crops-research-institute_1948

TABLE OF CONTENTS

	Page
INTRODUCTION	9
I. EXPERIMENTAL RESULTS OF 1948	
1. Tomatoes	13
2. Cucumbers	20
3. Lettuce	20
4. Mushrooms	20
5. Carnations	21
II. PLANT DISEASES	
1. *Didymella* investigations	24
2. Virus diseases :	
(*a*) Investigation of possible viricides	30
(*b*) The effect of heat treatment on mosaic disease of *Solanum capsicastrum*	32
3. Microbial antagonism and antibiotic substances	37
III. ANIMAL PESTS	
1. Tomato leaf miner	43
2. Red spider mite	51
3. Studies upon Thysanoptera	53
4. Insecticide investigations	57
IV. CHEMICAL PROBLEMS	
1. Nitrification studies	62
2. The use of alginates as a source of organic carbon in soil	70
3. Soil sterilization studies	72
4. The effect of some acute mineral deficiencies on glasshouse plants	73
5. The occurrence and correction of magnesium deficiency in *Solanum capsicastrum* under commercial conditions	80
APPENDIX	
A. Publications	82
B. Manurial treatments	87
C. Manurial treatments	89
D. Cultural operations	89
E. Meteorological Records, 1948	90

Diagram showing arrangements of Experimental Plots in 1948

INTRODUCTION

It is a pleasure to report that the work of the Research Station continues its steady progress in all departments. A limit to further developments, however, is being imposed by insufficient laboratory accommodation, and the staff is looking forward to the time when the proposed new research station for glasshouse crops has materialised.

Current Investigations

In view of the labour involved in attending to the " tops " of tall tomato plants trained in the customary fashion, an experiment was arranged to train them to a system of horizontal wires, as a ceiling, placed seven feet above ground. The highest parts of the plants could be reached by a worker of average height standing on a box, instead of a pair of steps. The time employed in " tying," etc., was reduced considerably in this way and crop yields varying according to variety from 43 to 54 tons per acre were obtained.

Cardboard boxes treated with Cuprinol were used successfully in the cultivation of tomatoes. The boxes were in a good state of preservation at the end of the season, and no injury was caused to the plants.

The effect of magnesium sulphate on the tomato was tested as a base dressing before planting, a top dressing during the season and by spraying the foliage with a 2 per cent. solution. Certain interesting observations were made regarding blotchy ripening of the fruit, but it would be unwise to draw any conclusions from the experiments at this stage.

Applications of top dressing fertilisers to the tomato in solid and solution forms were compared. Neither treatment proved superior to the other for the appearance of the plants and the weight of crop produced by the two treatments were similar.

Last year the use of sulphate of ammonia as the sole source of nitrogen gave a higher yield of tomatoes than the standard treatment. As this was an unexpected result the experiment was repeated in 1948. This year there was no difference in yield between the two treatments.

The experiment started in 1947 to determine the effects of omitting lime and phosphate from the tomato fertilizer programme was continued. The yields from all plots were high and at the end of this the second year of the experiment, no obvious effect can be recorded.

In the variety trials an English variety Downes seedling and a Dutch variety Bruinsma headed the list with yields of 61 tons per acre. The quality of the former is very good, but the latter is a Potentate type and the quality was inferior to that of Downes Seedling.

The cucumber crop this year was poor owing to an outbreak of root eelworm, *Heterodera marioni*, and also an invasion of bees which " set " the fruit from July onwards. The application of top dressings either as solutions or in the solid form gave equal results, but in the absence of any top dressing treatment the yield was reduced by some 25 per cent.

No effect was observed from a single application of magnesium sulphate at the rate of 8 ozs. per yard run while the beds were being prepared.

Cheshunt 5B lettuce fulfilled its earlier promise by maturing 8 days earlier than Cheshunt Early Giant.

Mushrooms grown in standard beds of horse manure compost yielded 1·9 lbs. per square foot, in comparison with 1·2 lbs. per square foot from the best of a number of synthetic compost plots.

The standard beds were dug over and sterilized by steaming after the crop had finished. On re-spawning, the production of mushrooms was negligible. A slight improvement was obtained by mixing 10 per cent. fresh horse manure with the sterilized beds, but nevertheless the yield was very small.

In experiments with tomatoes growing in pots, no relation could be found between manurial treatment and infection by *Didymella lycopersici*. Excess of magnesium, boron and manganese did not appear to influence infection.

Numerous attempts have been made to discover a method of isolating *Didymella* from the soil free from contaminating bacteria. No completely satisfactory method has been found, but the incorporation of rose bengal in the medium appears to eliminate the most troublesome forms.

A fumigation method has proved successful for sterilizing fresh tomato stems and wheat straw. On both of these media, *Didymella* has fruited well in pure culture.

The virus investigations were concerned with the possibility of preventing infection by spraying the plants with solutions likely to inactivate any virus on the outside of the leaves and also with the heat treatment cure of mosaic disease in *Solanum capsicastrum.*

A spray containing 1 per cent. solution of tannic acid applied on two consecutive days reduced by 50 per cent. the number of plants infected.

Solanums infected with mosaic were cured by exposure to a temperature of 105° F. for 12 hours per day on four consecutive days, when the concentration of virus within the plants was low.

From an examination of tomato seedlings attacked by leaf-miner collected recently in glasshouses, it would appear that only one (and not two as previously supposed) species of leaf-miner is involved in infestations upon commercial nurseries, and the correct name for it is *Liriomyza solani* Her.

Observations upon the adult flies have shown that a single female fly may lay about one hundred eggs and as it distributes them over a large number of seedlings in the propagating houses, emergence of a small proportion of puparia, which had lain dormant in the soil beneath the staging, may result in severe infestation of the seedlings.

Flies emerged from puparia, collected in March and April, at very irregular intervals, irrespective of conditions of temperature and moisture, and it is therefore not possible to predict what interval of time is likely to elapse between two generations of the insect.

The flies deposited as many eggs in the cotyledons of seedlings raised in soil to which either sulphate of potash or dried blood had been added as in those seedlings growing in a standard soil. After the eggs had hatched, the former plants, owing to their unbalanced growth, were more liable to collapse as a result of the larvæ feeding in their tissues.

A powder containing 5 per cent. BHC killed, by contact, adult flies much more rapidly than one containing 5 per cent. DDT. In small scale experiments, application of either powder effected a reduction in the number of eggs laid in the cotyledons, but did not afford complete protection to the seedlings. As a reduction was also obtained when an inert powder (kaolin) containing no insecticide was applied to them, it was concluded that a deposit of any powder upon foliage made it difficult for the flies to insert their eggs into the tissues. Application of BHC powder to older plants in pots was more effective in affording protection to them than that of DDT powder.

A large proportion of larvæ survived and formed their puparia normally after burying themselves in soil to the surface of which either DDT or BHC powder had been applied: after emergence from the puparia, a number of adult flies survived after making their escape from the soil which had been dusted with DDT powder.

Examination of Red Spider Mites collected on a commercial nursery from tomato plants and peach trees after treatment with azobenzene projected into the atmosphere of a block of glasshouses by the " smoke " method, showed that the great majority of eggs and resting nymphal stages of the mite had been killed, but that considerable numbers of active nymphs, especially those in the 3rd instar, and some adult mites had survived. These adult mites, on transference to fresh foliage, deposited many eggs, all but a few of which were viable.

Eggs of the mite were kept under varying conditions of temperature and light intensity, in an attempt to determine the reason for a high proportion, at times, failing to hatch. It was concluded that, for reasons at present unknown, some eggs fail to hatch, usually when the larval mite is fully developed within the shell, and that these unhatched eggs tend to accumulate upon the older leaves of plants.

A study has been made of British species of the genus Aeolothrips. The males of closely allied species in this genus are readily separable upon structural characteristics, but differences between the females are less marked. Variations within the species pertaining to characteristics used in the past for the separation of the species have been investigated.

The toxity of compounds having structural similarity with azobenzene, to the eggs of the glasshouse Red Spider Mite (*Tetranychus telarius* L.) has been investigated by means of a dipping technique. Interpretation of the results is difficult owing to the heterogencity of the test material. Of the substances tested only azoxybenzene and hydrazobenzene were as toxic as azobenzene. Tests were also made with organic phosphorus insecticides both in the laboratory and in glasshouses. Hexa-ethyl tetraphosphate (HEPT) and tetra-ethyl pyrophosphate (TEPP) are without appreciable ovicidal action on the eggs of the glasshouse Red Spider Mite though highly toxic to active stages. Tomatoes and chrysanthemums are susceptible to injury by these substances. E605 has a decided ovicidal action and furthermore may provide sufficient residual toxicity to destroy larvæ on emergence from eggs several days after its application.

Sprays containing HEPT and TEPP have proved effective in controlling aphids on carnations. Much less satisfactory results were obtained with HETP and TEPP aerosols.

Preliminary work has shown that E605 dispersed in aerosols or smokes is effective for controlling the glasshouse Red Spider mite and a number of other glasshouse pests.

Dusts containing DDT and BHC have been shown to injure tomato seedlings.

In 1947 it was shown that percentage nitrification of commercial hoof and horn in soil is independent of the concentration of the fertiliser in soil within fairly wide limits. During this year the same conclusion has been confirmed for hoof also, for nitrate production from these two fertilisers has been found directly proportional to the amounts added initially to the soil. These results are in contrast to those found for materials such as urea, Peruvian Guano and ammonium salts, which nitrify relatively rapidly in the soil.

In an experiment of short duration it was found, as expected, that nitrification of commercial horn varies inversely as the particle size.

The effect of added organic carbon on nitrification has been studied. Various amounts of starch mixed with soil at the same time as the material to be nitrified cause rapid disappearance of ammonia added in the form of ammonium sulphate or diammonium hydrogen phosphate. Starch also reduces the final levels of nitrate produced from the same compounds. The effect of carbon added in the same molecule as the nitrogen has been examined for the amino-acids glycine and tyrosine. So far as any conclusion is justified on such limited evidence it conforms to that indicated by the starch experiments, namely, that the lower carbon : nitrogen ratio produces the higher level of nitrification. Further work on these lines is in progress and the possibilities of rapid organic carbon determinations are being explored.

Apparent discrepancies in the nitrification of different samples of hoof and horn have led to the conclusion that " calcining " this material accelerates nitrification and this suggests that study of the effects of heat on this and similar products will prove profitable.

Serious differences in the methods of application of the phenoldisulphonic acid method for nitrate estimations described in the literature have made it necessary to examine this method which was used extensively in our earlier nitrification work. We conclude that it is not so accurate as the Devarda reduction method. Some of our earlier experiments which we regarded as critical have been repeated using the Devarda technique and in no case has it been necessary to modify the conclusions already made.

Work on alginates as a possible source of organic carbon in soil has been continued. Four products have been examined, namely, alginic acid, ammonium alginate, sodium alginate and calcium alginate. Initially samples of food quality were used but more recently cruder samples have been examined with no apparent difference in results. So far experiments have been confined to mixtures used for propagation of tomatoes, and the results show that for sowing and potting the addition of 0·5 or 1 per cent. of all except ammonium alginate gives results as good as or better than standard mixtures in which peat or stable manure constitute the source of organic matter added. For every soil used ammonium alginate has depressed growth and on occasion has produced almost toxic effects. Recently trials have been carried out with calcium alginate at six different centres under strictly commercial conditions with varied results. On one nursery the owner reported that the young plants were better than those produced in his own standard mixture. On two nurseries there was no difference between the alginate plants and those produced with ordinary standard mixtures. On the fourth nursery growth was poor and on the fifth the alginate was a complete failure ; seeds germinated unevenly and the resulting seedlings were very stunted. In the sixth nursery results were obtained which confirmed the curious behaviour of calcium alginate in several previous trials. It has frequently happened that compared with standard composts calcium alginate has caused a slower rate of growth in the very early stages. Later the rate is accelerated and eventually plants in calcium alginate composts have been as good as or better than those in standard mixtures. Whereas sodium alginate goes into colloidal solution easily and its function in soil is understood on this basis, calcium alginate is quite insoluble and presumably decomposition is necessary before it is effective. Base exchange will not account for its behaviour because levels of calcium in these mixtures are relatively high, and the suggestion is that microorganisms attack the alginate to produce a substance which will give either a true solution or a colloidal solution. This substance would appear to be more effective than sodium alginate. This hypothesis explains why different soils give different results when calcium alginate is added to them in that the decomposition postulated will depend on certain types of soil population which will not be common to all the soils used.

The micro-biological aspect of this and the nitrification problem would seem to be highly important.

Work has begun on the chemical effects of steam sterilisation. A rich cucumber soil sterilised

in the normal commercial way was sampled frequently for seventy-seven days after steaming. Initially the nitrate-nitrogen concentration was 240 p.p.m. and the ammonia-nitrogen 1 p.p.m. During the period of observation the former rose to a maximum of 365 p.p.m. and on the seventy-seventh day stood at 329 p.p.m. Ammonia-nitrogen showed a maximum of 46 p.p.m., being over 40 on the seventy-seventh day. On an adjoining unsterilised plot values were invariably lower, the ammonia-nitrogen never rising above 5 p.p.m. When some of the same soil was sterilised in the laboratory nitrate values were no higher than in the unsterilised counterpart. Ammonia values, however, showed a decided increase, being 53 p.p.m. on the thirtieth day.

Determinations on a maiden loam gave somewhat unexpected results. This soil, steamed as for propagating purposes, showed an appreciable increase (from 29 to 47 p.p.m. in twenty-two days) in nitrate concentration, but a much greater increase (from 5 to 146 p.p.m.) in ammonia concentration.

Observations of the effects of some acute deficiencies in *Asparagus plumosus namus*, *Solanum capsicastrum* and three varieties of chrysanthemums have been recorded. In general, when the young plants have been raised in complete nutrient and grown on for some time, the omission of either manganese or iron has little effect, the latter inducing a mild chlorosis. Under the same conditions omission of calcium, boron or magnesium, however, is followed by definite and sometimes acute effects. In the case of the *Asparagus plumosus*, for instance, omission of calcium does not appear to affect the production of shoots at the base, but these never grow above a height of 1½ ins., when they change colour and die back. With boron deficiency, however, the shoots grow to a height of 2½ ins., and have an orange colour, but while they make no growth they do not appear to die for a very long time. In the case of *S. capsicastrum* omission of calcium reduces growth and causes serious lack of colour in the leaves, which eventually become seriously desiccated at the tips. Few flowers are produced and these fail to set. Omission of boron on the same subject restricts growth so that new shoots produce rosettes of small leaves. Whereas in neither case is there appreciable shedding of leaves where magnesium is omitted in *S. capsicastrum*, practically all the foliage is lost at the time flowers would be expected to set. In the case of chrysanthemums there is a considerable difference in the reactions of different varieties to these deficiencies. Again calcium omission has a very deleterious effect, the growing points dying and death progressing backwards down the shoot, although some of the older leaves lower down the plant maintain a good colour throughout the season. The effects of some of these deficiencies on the roots are reported.

Magnesium deficiency of the Winter Cherry (*Solanum capsicastrum*) under commercial conditions has been investigated. This disorder causes serious losses to growers and where it occurs few if any of the plants are of the first marketable quality. The initial signs are loss of colour in the leaves generally, and occasionally interveinal yellow areas. This is in sharp contradistinction to magnesium deficiency in tomatoes, where interveinal yellowing is characteristic and general. Where the deficiency is acute serious defoliation occurs and it usually happens that by Christmas the plants are practically denuded of leaves. Spraying with 2 per cent. Epsom Salts solution which we have already recommended for tomatoes obtained little response from *Solanum capsicastrum*. A stronger solution caused some injury and but little better response. Examination of the soil showed that the magnesium soluble in semi-normal acetic acid was some 25 per cent. higher in pots carrying the sprayed plants and it is suggested that this was responsible for such response as was observed. Eventually this solved the problem, and we now add Epsom Salts each time a fertiliser is applied to the plants. The amount applied should be equal to the actual sulphate of potash used or to that which corresponds to the amount of potash (K_2O) in mixtures. On one nursery the good marketable crop was only 0·07 per cent. of the total in 1946. In 1947, using the Epsom Salts procedure, the marketable crop was over 99 per cent. of the whole and a rather better result was obtained in 1948.

EXPERIMENTAL RESULTS OF 1948

1. TOMATOES

The practice of grading the tomato fruits from the experimental plots, adopted in 1921, was continued:—

A. " Pinks " number 5 to 7 and " Pink and White " 8 to 10 to the lb. These are the best quality of fruit in size, shape and colour; " Pinks " being slightly larger than " Pink and Whites."
B. " Whites." These fruits are of good colour but smaller than " Pink and White."
C. " Blues." This grade consists of fruits of good colour but larger and more irregular in shape than Grade A.
D. " Roughs." Small mis-shapen fruits about the size of cherries.
E. Blotchy fruits which ripen irregularly.
F. Fruits showing Blossom End Rot.
G. Fruits showing the lesions of Streak Disease.
H. Fruits showing " Green Back."

(a) House 1: Training the top growth parallel to the ground at a height of 7 feet.

To save the labour of using steps when handling the top growth of the plants, roof wires were arranged as a ceiling at a height of 7 ft. above the ground, and the " tops " were trained horizontally by tying them to these wires. The workers raised themselves sufficiently to carry out the work by standing on boxes, which are much easier to move about than the usual nursery steps. Short jointed varieties were selected for trial, the results being given in Table I. Satisfactory yields were obtained from Crystal (54·34 tons per acre), Ogier's KCB (45·65 tons) and Single Cross (43·62 tons). These yields were slightly lower than those obtained in adjoining houses, but as the method is new to the workers in the houses, further experience should lead to increased yields. The experiment will be repeated in 1949.

(b) House 3

The experiments in this house were designed to obtain more information regarding " blotchy ripening."

In plots 1 and 6 the plants were planted in cardboard boxes, 8 ins. by 8 ins. by 8 ins., standing on the ground. A tile was placed underneath each box and kept there until the 4th truss had set. Then it was pulled out and the roots allowed to grow downwards into the soil beneath. In plots 2 and 5 the soil was flooded very heavily with water during the winter and the plants in plots 4 and 8 were sprayed every 3 weeks with a minor element solution. Plots 3 and 7 received standard treatment as controls. The results are given in Table II. The varieties were Ragworth Beauty and Melville Castle. Blotchy ripening was negligible where the plants were grown in cardboard boxes, and there was only a small amount in the controls. It was greater where the soil was very heavily flooded in the winter and still greater where the plants were sprayed with the minor elements solution.

(c) House 4

The deficiency experiments which have been continued since 1916 still produce the same type of result as they have done previously. The omission of either nitrogen or potash reduces the yield considerably, but the omission of phosphate has little effect, although in this case it must be noticed that the young plants were well supplied with phosphate in the pot stage. Blotchy ripening, as usual, was very high in the unmanured plot, and where either nitrogen or potash was omitted. It was negligible where phosphates were withheld.

Leather waste replaced hoof and horn in the base treatment of plot 7 and was given in addition to it in plot 4. No injurious effects were observed.

The results are given in Table III.

(d) House 5

In plot 3, the plants were grown in ordinary cardboard boxes; in plot 6, they had been treated thoroughly with Cuprinol before use. The yields 59·81 and 60·11 tons per acre were the highest obtained in the house. The effect of the Cuprinol was striking for the treated boxes shewed no signs of decay at the end of the season, while the ordinary boxes were badly rotted.

In plots 7 and 8 the soil was injected with DD as a control for the tomato root eelworm, 3 weeks

TABLE I

VARIETY TRIALS : LOW ROOF WIRES

House	Plot	Variety	Crop Yield in Lbs. per Plant							Total Tons per Acre	% Blotchy Fruit
			May	June	July	Aug.	Sept.	Oct.	Total		
1	1	Single Cross	0·02	1·88	2·20	0·68	0·76	0·20	5·74	43·62	0·50
1	2	Crystal	0·01	1·39	3·18	1·08	1·21	0·28	7·15	54·34	18·46
1	3	Ogier's K.C.B.	—	1·75	1·95	1·13	0·83	0·35	6·01	45·65	0·50
1	4	Balch's Gem	—	1·28	1·11	0·43	0·33	0·13	3·28	24·91	4·27
1	5	Bruinsma	—	1·75	2·07	0·63	0·45	0·19	5·09	38·68	0·99

TABLE II

VARIETY.—PLOTS 1–4: RAGWORTH BEAUTY. PLOTS 5–8: MELVILLE CASTLE.

House	Plot	Treatment	Crop Yield in Lbs. per Plant							Total Tons per Acre	Average Tons per Acre	% Blotchy Fruit
			May	June	July	Aug.	Sept.	Oct.	Total			
3	3	Control	—	1·61	1·55	0·78	0·61	0·12	4·67	35·49	33·97	0·22
3	7	"	0·03	1·70	1·36	0·92	0·14	0·12	4·27	32·45		0·24
3	1	Planted in cardboard boxes: tiles beneath at first ...	0·16	2·00	1·34	1·08	0·76	0·28	5·62	42·71	39·37	—
3	6	" " "	0·15	1·85	1·01	0·90	0·70	0·13	4·74	36·02		0·19
3	2	Heavy winter flooding ...	—	1·79	1·72	0·99	0·70	0·12	5·32	40·43	39·22	0·74
3	5	" " " ...	—	1·65	1·76	0·87	0·55	0·17	5·00	38·00		1·21
3	4	Sprayed with minor element solution	—	1·75	1·79	0·79	0·62	0·12	5·07	38·53	32·34	1·17
3	8	" " "	0·07	0·61	1·30	0·84	0·47	0·15	3·44	26·14		2·90

TABLE III

VARIETY : AILSA CRAIG.

House	Plot	Treatment	Crop Yield in Lbs. per Plant							Total Tons per Acre	% Blotchy Fruit
			May	June	July	Aug.	Sept.	Oct.	Total		
4	1	No nitrogen	0·21	2·17	0·48	0·32	0·12	0·09	3·39	25·76	1·74
4	2	Unmanured	0·11	2·00	0·72	0·52	0·22	0·08	3·65	27·74	29·31
4	10	No potash	0·17	1·91	1·09	0·88	0·26	0·06	4·37	33·21	50·81
4	9	No phosphates	0·16	2·43	1·72	1·18	0·19	0·17	5·85	44·46	0·18
4	3	Complete artificials	0·09	2·37	1·64	0·94	0·45	0·38	5·87	44·61	0·15
4	8	Complete artificials plus horse manure ...	0·08	2·37	1·97	1·08	0·43	0·26	6·19	47·04	0·49
4	4	Leather waste 4 ozs. per sq. yd. plus standard treatment	0·11	2·49	1·95	1·22	0·46	0·21	6·44	48·86	0·30
4	7	As plot 4, but without hoof and horn ...	0·09	2·42	1·96	1·11	0·34	0·25	6·17	46·74	0·32

TABLE IV

VARIETY: POTENTATE.

House	Plot	Treatment	Crop Yield in Lbs. per Plant							Total Tons per Acre	% Blotchy Fruit
			May	June	July	Aug.	Sept.	Oct.	Total		
5	5	Standard treatment without lime: Control	0·12	2·87	1·57	1·48	0·93	0·69	7·66	58·21	2·08
5	4	As plot 5 but 1 lb. flowers of sulphur per square yard	0·20	2·93	1·51	1·48	0·90	0·55	7·57	57·53	2·10
5	2	Standard treatment and peat	0·24	2·96	1·33	1·16	1·06	0·60	7·35	55·86	1·36
5	1	Standard treatment with straw composted by Sulphate of Ammonia	0·31	3·11	1·23	1·05	0·74	0·57	7·01	53·27	3·00
5	7	Standard treatment. Soil injected with D.D.	0·21	2·21	1·25	1·34	0·76	0·73	6·50	49·40	1·23
5	8	As plot 7	0·34	2·09	1·21	1·14	1·01	0·74	6·53	49·62	1·37
5	3	Planted in cardboard boxes	0·19	3·02	1·32	1·47	1·06	0·81	7·87	59·81	2·29
5	6	As plot 3 but boxes treated with Cuprinol	0·07	2·93	1·43	1·53	1·02	0·93	7·91	60·11	2·91

before planting. Some slight injury was noticeable in the plants, for the batch was uneven, but they recovered reasonably quickly. The crop, however, was less than in the other plots in the house.

Plot 4 was unlimed and treated with 1 lb. flowers of sulphur per square yard as in previous years. The plants and crop were similar to those in the unlimed control, plot 5. The addition of peat to plot 2 and straw composted with sulphate of ammonia to plot 1, were without effect.

The results are given in Table IV.

(e) House 7: Magnesium sulphate

The experiments in this house were concerned with the use of magnesium sulphate. Plots 3 and 7 received standard treatment as controls. In plots 2 and 5 magnesium sulphate was applied to the soil before planting, at the rate of 8 ozs. per square yard. Plots 2 and 5 received one top dressing 6 weeks after planting and another 4 weeks later at the rate of 2 ozs. per square yard, while the plants in plots 1 and 6 were sprayed three times with a 2 per cent. solution. The results given in Table V. show that total yields from all treatments, except where magnesium sulphate was applied as a top dressing, were practically the same. The percentage of blotchy ripening was high in all plots, and especially so from the two plots receiving magnesium sulphate as a top dressing and one plot receiving the spray treatment. It is unwise to draw any conclusions regarding this result at this stage and the problem will be investigated further.

(f) House 7: Solid fertilisers versus solutions

In this house 4 plots received standard treatment with the usual fertilisers, while to 4 others, the top dressing treatment was applied in solution form by means of the " Solufeeder."

Results given in Table V shew little difference either between total yields, or in the amount of blotchy ripening. It seems therefore, that the necessary top dressing treatment can be applied with equal effect in either the solid or solution form.

(g) House 9: Sulphate of ammonia

Last year an experiment was conducted in this house, whereby standard fertiliser treatment was applied to the west side of the house, while on the other side the nitrogen in the fertiliser was given in the form of sulphate of ammonia. The results showed an appreciable increase in favour of sulphate of ammonia. As this was unexpected the experiment was repeated in 1948. As will be seen in Table V, there was no difference in yield this year, although slightly less blotchy ripening occurred where sulphate of ammonia was used.

(h) House 10

In 1947, an experiment was arranged in which the effect of winter flooding of the soil was compared with that of watering the subsoil by means of straw walls inserted in the ground before planting. The average yield 50·84 tons per acre from the straw plots was so much higher than that from the winter flooded plots—39·88 tons per acre— that this experiment was repeated in 1948.

The results are given in Table V, and this time there was no difference in yield between the two treatments. Clearly some other factor was in operation in 1947.

(i) Houses 11 and 12: The effect of omitting lime and phosphate from the fertiliser treatment

The experiment commenced in 1947, will be continued each year until an obvious result is obtained.

Plots 1 and 2 in House 11 received standard treatment.

Plots 3 and 4 received the same treatment without lime.

Plots 1 and 2 in house 12 received standard treatment without phosphate.

Plots 3 and 4 received standard treatment without either lime or phosphate.

The results are given in Table VI. The yields from all plots in the two houses were high. Variation is apparent, but it is too early in the life of the experiment to attempt an explanation.

(j) Variety Trials in the Rose House

The results of these trials are given in Table VII. Downes seedling and Bruinsma head the list with 61 tons per acre. Downs Seedling is a sunrise type producing high quality fruit and is well worth a trial by nurserymen, as is Dufferns Seedling and ES4 —both good quality tomatoes.

TABLE V

VARIETY.—HOUSES 7 AND 8: POTENTATE. HOUSE 9: E.S.5. HOUSE 10: SINGLE x J.B. AND OGIERS K.C.B.

House	Plot	Treatment	Crop Yield in Lbs. per Plant							Total Tons per Acre	Average Tons per Acre	% Blotchy Fruit
			May	June	July	Aug.	Sept.	Oct.	Total			
7	3	Control	0·15	4·19	2·28	1·12	1·24	0·74	9·72	73·87	73·73	8·03
7	7	,, ...	0·09	3·94	2·27	1·02	1·21	1·15	9·68	73·58		8·58
7	2	Magnesium sulphate 8 ozs. per sq. yd. applied to base	0·65	3·75	2·31	1·32	1·27	0·90	9·70	73·71	70·71	7·41
7	5	,, ,, ,,	0·03	3·92	2·19	0·86	1·09	0·82	8·91	67·71		7·75
7	4	Magnesium sulphate applied as top dressing	0·06	4·45	2·77	1·40	1·47	1·02	11·17	84·89	76·95	12·08
7	8	,, ,, ,,	0·05	3·53	2·48	1·00	1·16	0·86	9·08	69·00		12·55
7	1	Magnesium sulphate sprayed over foliage	0·11	3·33	2·79	1·31	1·55	0·88	9·97	75·75	72·57	13·46
7	6	,, ,, ,,	0·10	4·18	2·08	0·79	1·14	0·84	9·13	69·39		7·66
8	1	Standard base and top-dressing treatment ...	0·13	3·59	1·96	0·73	1·00	0·54	7·95	60·42	62·76	7·6
8	3	,, ,, ,,	0·09	3·87	1·68	0·77	1·25	0·84	8·52	64·75		6·22
8	5	,, ,, ,,	—	3·65	2·06	0·77	1·43	1·02	8·93	67·86		7·51
8	7	,, ,, ,,	0·02	3·22	1·91	0·76	1·72	—	7·63	57·99		7·73
8	2	Standard base: top-dressing applied in solution form	0·06	3·61	1·90	0·81	1·39	0·67	8·44	64·14	64·77	5·21
8	4	,, ,, ,,	0·06	3·87	1·76	0·95	1·19	0·90	8·73	66·35		4·92
8	6	,, ,, ,,	0·02	3·38	2·19	0·69	1·45	0·87	8·60	65·37		7·56
8	8	,, ,, ,,	0·03	3·48	2·22	0·71	1·88	—	8·32	63·23		8·53
9	1	Nitrogen as sulphate of ammonia	0·17	2·54	1·84	0·83	1·14	—	6·52	49·55	47·80	0·61
9	2	,, ,, ,,	0·08	2·89	1·72	0·72	0·65	—	6·06	46·05		0·82
9	3	Standard treatment ...	0·04	2·61	1·73	0·77	0·72	—	5·87	44·61	46·17·	1·36
9	4	,, ,, ,,	0·06	2·51	1·76	0·77	1·18	—	6·28	47·72		1·43
10	1	Winter flooding	0·02	2·51	2·39	0·75	1·17	—	6·84	51·92	55·30	1·32
10	3	,, ,, ...	—	2·20	2·94	1·13	1·45	—	7·72	58·68		1·43
10	2	No winter flooding: straw walls	0·0	2·32	2·56	0·87	1·17	—	6·92	52·59	54·87	2·31
10	4	,, ,, ,,	0·01	2·44	2·58	0·94	1·55	—	7·52	57·15		0·13

TABLE VI

VARIETY.—HOUSE 11: PLOT 2 AND 3, L.M.R. No. 1; PLOT 1 AND 4, E.S.I. HOUSE 12: PLOT 2 AND 3, L.M.R. No. 1; PLOT 1 AND 4, E.S.1.

House	Plot	Treatment	Crop Yield in Lbs. per Plant							Total Tons per Acre	Average Tons per Acre	% Blotchy Fruit
			May	June	July	Aug.	Sept.	Oct.	Total			
11	1	Standard	0·04	1·85	2·39	1·48	1·68	—	7·44	56·54	52·89	0·79
11	2	,, ...	0·05	1·74	1·55	1·17	1·38	0·59	6·48	49·24		1·55
11	3	No lime	0·02	1·94	1·45	1·26	1·05	1·18	6·90	52·44	55·18	1·01
11	4	,, ,, ...	0·11	2·03	2·15	1·39	1·27	0·67	7·62	57·91		0·66
12	1	No phosphates	0·12	2·17	1·87	1·30	1·24	0·75	7·45	56·62	54·42	—
12	2	,, ,, ...	0·04	2·10	1·30	1·08	1·32	1·03	6·87	52·21		0·44
12	3	No phosphates and no lime	0·05	2·00	1·52	1·10	1·37	1·13	7·17	54·49	58·56	0·42
12	4	,, ,, ,,	0·13	2·17	2·49	1·55	1·40	0·50	8·24	62·62		0·23

TABLE VII

VARIETY TRIALS IN ROSE HOUSE.

Plot	Variety	Crop Yield in lbs. per Plant							Total Tons per Acre	% Blotchy Ripening
		May	June	July	Aug.	Sept.	Oct.	Total		
1	Downe's Seedling	0·34	3·93	1·41	1·75	0·64	—	8·07	61·33	0·50
2	Bruinsma	0·22	3·34	2·14	1·35	0·99	—	8·04	61·10	0·37
3	Swardson's Early	0·58	3·14	1·27	1·70	0·94	—	7·63	57·98	0·12
4	E.S.4	0·26	3·01	1·58	1·40	1·23	—	7·48	56·85	0·41
5	Carey's Variety	0·32	3·34	1·42	1·62	0·69	—	7·39	56·16	1·48
6	P x P No. 1	0·34	2·72	1·63	1·62	0·97	—	7·28	55·33	1·78
7	Clapham's Commander	0·37	3·24	1·72	1·41	0·54	—	7·28	55·33	0·69
8	Kondine Red	0·54	3·17	1·11	1·51	0·89	—	7·22	54·87	4·15
9	Duffern's Seedling	0·37	2·97	1·23	1·50	0·80	—	6·87	52·21	—
10	Gerrard's Ailsa Craig	0·42	2·36	1·68	1·50	0·80	—	6·76	51·37	3·54
11	Stonor's All Clear	0·46	2·76	1·00	1·28	1·13	—	6·63	50·38	0·44
12	Vetomold	0·12	2·84	1·05	1·01	1·44	—	6·46	49·09	0·47
13	Mrs. Underwood's Variety ...	0·56	2·38	1·32	1·31	0·64	—	6·21	47·19	0·95
14	Charlie's Own	0·11	2·53	1·42	1·33	0·47	—	5·86	44·54	1·04
15	Baby Lea	0·56	2·56	0·86	1·09	0·73	—	5·80	44·08	0·87
16	Paul's Quality	0·27	2·37	0·94	1·07	0·79	—	5·44	41·34	1·84

TABLE VIII

VARIETY: BUTCHER'S DISEASE RESISTER.

Plot	Treatment		Crop Yield in Lbs. per Plant							Total Tons per Acre	Average Tons per Acre	Total Flats per Foot	Average Flats per Foot
	Base	Beds	Apr.	May	June	July	Aug.	Sept.	Total				
D2	Steamed	Magnesium sulphate added	2·20	12·45	9·56	5·99	2·48	9·71	42·39	63·58	66·08	1·32	1·37
D4	,,	,, ,, ,,	3·19	15·70	10·79	5·31	1·76	8·98	45·73	68·59		1·42	
E2	,,	Straw walls	2·83	12·77	7·15	2·57	0·69	4·34	30·35	45·52	51·34	0·94	1·06
E4	,,	,, ,, ...	2·18	14·63	9·12	4·36	1·61	6·21	38·11	57·16		1·19	
F5	,,	No fertilisers	4·18	11·18	7·89	4·82	2·89	1·83	32·79	49·18	42·18	1·02	0·87
G2	,,	,, ,, ...	2·38	8·73	5·62	3·68	2·33	0·72	23·46	35·19		0·73	
F3	,,	Standard treatment: fertilizers in solution form ...	3·02	12·44	8·31	5·46	5·81	3·57	38·61	57·91	60·25	1·20	1 25
G4	,,	,, ,, ,,	1·88	10·34	9·93	6·75	9·15	3·68	41·73	62·59		1·30	
D3	,,	Standard treatment: Control	1·67	12·42	9·83	6·20	2·06	7·65	39·83	59·74		1·24	
D5	,,	,, ,, ,,	2·96	15·38	10·20	3·88	1·19	4·12	37·73	56·59		1·18	
E3	,,	,, ,, ,,	2·29	15·02	7·51	3·72	1·00	7·36	36·90	55·35		1·15	
E5	,,	,, ,, ,,	3·17	13·46	10·76	5·93	1·32	6·80	41·44	62·16	57·23	1·29	1·19
F2	,,	,, ,, ,,	3·10	11·03	8·09	4·93	4·55	3·02	34·72	52·08		1·08	
F4	,,	,, ,, ,,	4·44	11·78	9·43	7·13	6·45	3·40	42·63	63·94		1·33	
G3	,,	,, ,, ,,	2·76	9·61	7·57	4·79	5·97	2·93	33·63	50·44		1·05	
G5	,,	,, ,, ,,	1·82	10·98	13·01	6·85	4·63	1·07	38·36	57·54		1·19	

Bruinsma, a Dutch importation, is a firm fruited variety, of the Potentate type, but the quality is not so good as the previously named varieties. PXP No. 1 is a selection from the station's leaf mould resisters, which is not quite ready for distribution. Careys variety is a small fruited type and rather sweeter than most varieties. Swardson's Early is a good variety but on steamed soil growth is rank, and the fruit coarse.

As the result of many years experiments it is possible to record the reaction of some better known varieties to steamed soil as follows :—

Group 1. Tomatoes that are suitable generally for cultivation in steam sterilised soil

Potentate, Vetomold, Single Cross, Buckley, JH2, and Baby Lee.

Group 2. Tomatoes that can be grown satisfactorily provided care is taken not to apply too much water during the early stages

ES1, ES4, ES5, LMR No.1, Bruinsma, Downes Seedling, Dufferns Seedling, Carrick, Kondine Red, Radio, Tuckswood, Freedom, All Clear, Ailsa Craig and Scarlet Knight.

Group 3. Tomatoes which, in steamed soil, produce too luxuriant growth or in which the fruits are either coarse, hollow or small

Market King, Melville Castle, Ogier's KCB, Balch's Gem, Charley's Own, Democrat, Swardson's Early, Bide's NCO and Recruit, Clucas's 99 and most of Stonor's varieties.

2. CUCUMBERS

The cucumber crop of 1948 was a very poor one due in the first place to a sudden development of root eelworm and secondly to an invasion of bees from July onwards owing to the scarcity of pollen in outdoor flowers. Despite all efforts they could not be kept out. The number of local bee keepers has increased greatly in past years and the insects are a real menace to the station cucumber crop for they " set " the blooms, produce seed fruit and reduce greatly the number of marketable seedless fruit.

The results of this years experiments are given in Table VIII. Standard treatment gave an average yield of 57.23 tons per acre.

In two plots, the fertilizers were applied in solution form comparable to the solid fertilizers used in the controls. Application was by means of the " Solufeeder." The yield of 60·25 tons per acre, suggests that fertilizer treatment is equally effective whether applied in the usual form or by means of nutrient solutions. In two other plots, all top-dressing fertilizers were withheld, and the crop yield fell to 42·18 tons per acre, a clear indication of the need for top dressing the cucumber crop.

Straw walls, were inserted across the beds at intervals of 24 inches in two plots. The increased root development and yield anticipated from this treatment did not materialize, probably due to the attack of root eelworm. The yield was 51·34 tons per acre.

In two plots a dressing of magnesium sulphate was mixed into the beds while they were being made, at the rate of 8 ounces per yard run. No effect could be observed on the foliage of the plants, but the yield of 66·08 tons per acre was slightly higher than from the controls.

3. LETTUCE

The winter lettuce trial was a comparison between Cheshunt Early Giant and the newer Cheshunt 5b. Young plants raised in seedtrays, were planted out in steam sterilized soil. Cutting commenced with Cheshunt 5b on March 2nd, and with Cheshunt Early Giant on March 10th.

Thus Cheshunt 5b fulfilled its earlier promise by maturing 8 days earlier than Cheshunt Early Giant. Cheshunt 5b is a smaller and more compact lettuce than Early Giant. It can be planted 8 in. × 8 in., instead of 10 in. × 11 in. which is usual for Cheshunt Early Giant. Cheshunt 5b, is also rather lighter in colour than Early Giant and is almost free from marginal scorch when grown in the proper manner.

4. MUSHROOMS

The mushroom experiments were concerned with a comparison between the cropping power of various synthetic composts and the best horse manure obtainable. The average yield in four months from the horse manure controls was 1·9 lbs. per square foot, but the best of the synthetics was only 1·2 lbs. per square foot, and the individual results are not worthy of recording.

On April 22nd, after four months cropping, the horse manure beds were turned over and sterilized by means of steam. No difficulty was experienced in securing a very thorough partial sterilization. The beds were then allowed two days to dry out before reconditioning. After this short rest the beds were gently compressed and were then only half the depth they were originally. Fresh

horse manure was mixed with some of the beds at the rate of one part manure to nine parts old bed, by volume. The manure was worked in thoroughly and then the beds were pressed down. The temperature of beds C and D, to which stable manure had not been added rose to 68°F. Where fresh horse manure was present, it rose to 82°F. for three days, then fell to 78°F. and after 3 weeks fell to 68°F.

Spawning took place on May 7th when the beds had dried out sufficiently to allow growth of the spawn. The spawn ran fairly freely in the beds to which stable manure had been added, but growth was not observed in the other beds. Casing was carried out on June 1st and 15 days later some mushrooms appeared on beds B, E and F containing the fresh horse manure. They were very small and in isolated patches. The appearance of mushrooms was spasmodic and there were no signs of a real " flush " of fruit bodies. The weights produced from the beds in 6 weeks were as follows : –

Treatment	*Crop weight in ozs. per 144 sq. feet.*	*Average weight in ozs. per 144 sq. feet.*
Beds steamed only.		
1	10	16
2	22	
Bed steamed : then 10 per cent. fresh horse manure added.		
3	189	171
4	184	
5	141	

As any weight less than $1\frac{1}{2}$ lbs. per square foot is a poor crop, it is obvious that any attempt to steam sterilize the old beds for a second crop, even after the addition of a proportion of fresh manure is useless.

5. CARNATIONS

In 1947 the north half of tomato house No. 2 was turned over to carnations, the south half having been used for hydroponics since 1944. Four beds were arranged as follows :—

No.	*Nature of bed*	*Length in feet*	*Width in feet*	*Area in sq. feet*
1	7 in. bed over a brick base ..	$40\frac{1}{2}$	4	162
2	7 in. bed in a concrete bench ..	$36\frac{1}{2}$	$3\frac{2}{3}$	$133\frac{3}{8}$
3	7 in. bed over a base of 2 in. tiles	$40\frac{1}{2}$	3	$121\frac{1}{2}$
4	7 in. bed over the top of the natural soil	$40\frac{1}{2}$	4	162

The beds were prepared and planted in June, 1947, except bed No. 2, which was not planted until August 1947, owing to delay in delivery of the concrete bench.

The compost was prepared by mixing 4 barrow loads of medium maiden loam with 1 barrow load of old cow manure. To this mixture was added $\frac{1}{2}$ per cent. by weight of lime, hoof and horn, bone meal and sulphate of potash. Top dressings were applied as necessary.

A serious set back occurred about the middle of December, 1947, when the heating system broke down at a time which coincided with severe frost. From December 16th to 18th, 17 degrees of frost were experienced outside and in the houses there were 11 degrees of frost. This did not kill the plants, but it prevented flowering for sometime. In this respect it was observed that the effect lasted the longest in the raised concrete bench and for the shortest time where the beds were placed over a brick base.

The results showing the number of flowers picked for 1947 and 1948 are given in the following tables.

It will be seen that the chilling effect of the December frosts was felt most severely by the plants in the raised concrete bench, and where the beds were placed directly on the ground. The plants in the bed placed over a brick foundation suffered least. Here flowering commenced in February, whereas in the other two beds it was delayed until April, except in the case of one variety.

The average number of flowers per plant is lower than would be expected from a satisfactory crop, but this is not surprising in view of the very serious frost injury in December, 1947. The variation from variety to variety will be watched carefully in future years.

TABLE IX

BED NO. 1.—BEDS OVER A BRICK BASE. PLANTED JUNE 9TH, 1947.

Variety	Number of Plants	Flowers per Month												Average Number of Flowers per Plant
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	
King Cardinal ...	66	1	28	67	102	35	103	106	65	54	39	18	6	624	9·45
Wivelsfield White ...	42	2	12	34	94	33	155	158	101	43	29	40	1	702	16·71
Pantaloon	30	—	5	13	29	33	80	73	42	44	16	30	6	371	12·36
Virginia	30	—	12	29	46	22	28	40	52	36	20	15	1	301	10·03
Mrs. Dixon	60	—	3	27	190	72	122	225	177	74	38	67	4	999	16·65
Spectrum Supreme ...	54	—	8	37	108	40	52	131	66	59	35	33	11	580	10·74
White Maytime ...	36	—	15	41	61	32	71	58	89	61	32	16	7	483	13·42
Maytime	6	—	—	7	17	7	14	16	25	13	4	2	2	107	17·83

TABLE X

BED NO. 2.—BEDS IN RAISED CONCRETE BENCH. PLANTED AUGUST 16TH, 1947.

Variety	Number of Plants	Flowers per Month												Average Number of Flowers per Plant
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	
King Cardinal ...	60	—	—	—	35	68	190	180	66	28	23	23	16	629	10·48
Wivelsfield White ...	36	—	—	4	60	55	227	135	53	29	33	31	5	632	17·56
Pantaloon	30	—	—	—	9	62	105	70	67	79	33	27	9	461	15·37
Virginia	42	—	—	—	58	65	102	83	43	43	11	21	4	430	10·24
Mrs. Dixon	48	—	—	—	3	61	221	283	111	77	21	36	15	828	17·25
Charming	24	—	—	—	—	27	86	63	27	18	8	4	3	236	9·83
White Maytime ...	18	—	—	—	54	55	42	28	18	15	18	20	14	264	14·66
Spectrum	18	—	—	—	2	16	52	60	22	16	10	13	8	199	11·05
Pink Treasure ...	12	—	—	—	7	18	34	14	10	14	13	13	4	127	10·58

TABLE XI

BED NO. 3.—BEDS OVER A DRAIN TILE BASE. PLANTED JUNE 9TH, 1947.

Variety	Number of Plants	Flowers per Month												Average Number of Flowers per Plant
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	
King Cardinal ...	60	—	2	27	77	69	115	119	79	33	20	14	7	562	9·36
Wivelsfield White ...	48	—	11	70	101	65	170	104	133	77	55	36	9	831	17·31
Pantaloon	48	—	4	35	60	58	107	75	88	73	28	38	26	592	12·33
Spectrum	48	—	2	28	98	55	80	148	58	21	28	22	7	547	11·40
Olivette	48	—	—	21	103	92	83	122	62	40	19	29	9	580	12·08
Charming	30	—	—	2	39	44	73	49	37	21	14	9	7	295	9·83
Clayton Crimson ...	30	—	—	7	33	47	64	76	39	12	9	7	5	299	9·97
Joy	12	—	1	5	10	3	31	17	5	5	1	1	1	80	6·67

TABLE XII

BED NO. 4.—BEDS OVER THE NATURAL GROUND. PLANTED JUNE 24TH, 1947.

Variety	Number of Plants	Flowers per Month												Average Number of Flowers per Plant
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	
King Cardinal ...	66	—	—	1	70	64	194	162	57	27	18	18	3	614	9·30
Wivelsfield White ...	42	—	—	27	89	41	228	121	96	56	33	27	6	624	14·85
Pantaloon	36	—	—	1	10	41	120	76	39	42	21	31	7	388	10·77
Olivette	48	—	—	1	37	97	115	215	87	42	21	17	9	641	13·35
Topsy	66	—	—	—	32	62	151	161	75	25	34	28	4	572	8·66
Pink Treasure ...	30	—	—	1	18	37	90	63	32	10	11	17	2	281	9·36
Spectrum Supreme ...	30	—	—	—	12	19	84	105	36	19	21	11	4	311	10·36

II. PLANT DISEASES

1. DIDYMELLA INVESTIGATIONS

By P. H. WILLAIMS

The investigations on *Didymella lycopersici* have been continued and have been concerned with the influence of manurial treatment on infection, the effect of temperature and soil moisture on survival in the soil, methods of isolation from the soil and experiments on spore production in pure culture.

(1) The influence of manurial treatment on infection

In the 33rd Annual Report an experiment was described in which tomato plants, variety Potentate, were grown in soil to which were added heavy dressings of sulphate of ammonia, nitrate of potash, sulphate of potash and superphosphate, either singly or in combination. It was found that in all cases where nitrogen was added to the soil, infection was severe while with potash and superphosphate alone or in combination it was much less.

During the present season an attempt has been made to obtain more precise information on this point.

A large quantity of soil was sterilized by steaming and stored for use during the season. For potting, one part of peat was mixed with nine parts of this soil together with appropriate amounts of lime, urea, sulphate of potash and superphosphate. A mixture of artificials based on the usual base dressings used in tomato growing was adopted as the standard treatment and the effect of each of the constituents was studied by varying its amount while keeping the remainder constant.

This standard mixture was as follows :—

Lime	0·05 per cent.
Superphosphate	0·04 per cent.
Sulphate of potash	0·06 per cent.
Urea	0·015 per cent.

It was found, however, that this quantity of base manure was insufficient for pot culture, owing to the heavy leaching and in later experiments it was increased five times to give the following formula :—

Lime	0.25 per cent.
Superphosphate	0·2 per cent.
Sulphate of potash	0.3 percent.
Urea	0·08 per cent.

One series of experiments was carried out with plants growing in size 32 pots and later repeated with plants in 10 in. pots. In the latter experiments a compost containing stable manure was used : the varieties were Potentate and Ailsa Craig.

In last season's experiments, scrapings from diseased tomato stems were inserted in the soil. This involved some damage to the roots and it was therefore arranged to insert a piece of glass tubing 1½ ins. long and 1 in. in diameter in the soil when potting. This tube could be filled with a culture on sand and oatmeal and then withdrawn. In this way the roots would not be damaged.

In an experiment on the effect of excess manganese carried out early in the season, in which this method was used, no infection occurred however, and it was therefore decided to compare it with other possible methods.

Forty plants, variety Potentate, were potted into size 32 pots. In ten, tubes were inserted as above, filled with a culture on sand and oatmeal and withdrawn, the culture being covered with soil. In ten, the top inch of soil was replaced with soil with which a culture of the fungus on sand and oatmeal had been mixed. 10 more plants received 50 mls. each of a spore suspension prepared from stems stored from the previous autumn. The remaining 10 plants served as controls. After 5 weeks the plants were cut out. The results given in the following Table I.

TABLE I.

Methods of Inoculation. (10 plants)

	Infected	*Wilting*
Culture in tubes ..	3	2
Culture in soil ..	6	4
Spore suspension ..	7	7
Control	0	0

The lesions on the plants infected with spores were on the average larger than those in the other treatments. It therefore appeared that the addition of a spore suspension was the most effective method of inoculation.

In a further experiment, the effect of varying amounts of spore suspension was determined. One series of 5 plants received 25 mls., a second 50 mls. and a third 100 mls. After 5 weeks, 3 of the plants receiving 25 mls. had become infected, compared with 4 in each of those receiving 50 mls. and 100 mls. There did not appear to be any advantage in using more than 50 mls. suspension and this was adopted as the standard treatment. The inoculum was applied 1 week after potting up the plants.

(a) The effect of nitrogen

In the first experiment, the first manurial formula was used. The plants, variety Potentate, were grown in size 32 pots : there were 10 plants in each series. They all became rather hard and no gradation in their conditon was observed. The results 5 weeks after inoculation are shown in Table II.

TABLE II.
The Effect of Nitrogen on Infection

Series	*Urea per cent.*	*No. infected out of 10 plants*
A	0·004	5
B	0·008	8
C	0·015	7
D	0·03	6
E	0·06	4

In a second experiment, using the second formula a definite gradation in the conditon of the plants was observed. After 14 days series X (0·02 per cent. urea) were slightly hard with a greyish appearance. With increasing nitrogen the appearance improved, those in series AA (0·15 per cent. urea) being very good. With 0·3 per cent. however, the plants were very dark green and stunted compared with series AA, suggesting that nitrogen was in excess of requirements. Two weeks later, the plants still showed the gradations in condition but were all much harder. The results are shown in Table III.

TABLE III.
The Effect of Nitrogen on Infection

Series	*Urea per cent.*	*No. infected out of 10 plants*	*No. wilting*
X	0·02	10	0
Y	0·04	10	3
Z	0·08	10	3
AA	0·15	9	5
AB	0·30	10	8

The experiment was repeated using the variety Ailsa Craig with the results shown in Table IV. No very definite gradations in the condition of the plants was observed.

TABLE IV.
The Effect of Nitrogen on Infection

Series	*Urea per cent.*	*No. infected*	*No. wilting*
AJ	0·02	4	0
AK	0·04	5	0
AL	0·08	8	3
AM	0·15	6	6
AN	0·30	3	3

It will be seen that in these experiments there were no definite indications that the amount of infection was conditioned by the amount of nitrogen in the soil.

In the previous year the effect of the addition of nitrogen was noticeable within a week after the plants had been potted. This year it was not so rapid in its effect possibly due partly to the smaller quantities used and partly to the duller season in which the effect would not be so great. It was felt therefore, that possibly the interval between potting and inoculation was not long enough for any differences to manifest themselves. Accordingly, two experiments were carried out using 10 in. pots which allowed for considerable growth to take place before hardening set in.

In the first experiment, Ailsa Craig plants were grown in a compost containing stable manure to which lime, superphosphate and sulphate of potash were added according to formula 2. Urea was used as source of nitrogen, being added at the rate of 0·3 per cent., 0·08 per cent. and 0·02 per cent. There were six plants in each series. After three weeks the plants receiving 0.3 per cent. urea were rather dark and stunted compared with the others and the stems rather thin. This suggested that the nitrogen was in excess. The other plants were good, those receiving 0·02 per cent. being slightly the taller and softer. Five weeks after potting they were inoculated by pouring 200 mls. of a spore suspension on the soil.

Owing to the lateness of the season, infection developed slowly, appearing first after 5 weeks in the series receiving 0.3 per cent. The full results are shown in Table V.

In a second experiment with Potentate no obvious differences were observed between the plants. The results are also shown in Table V.

TABLE V.

The Effect of Nitrogen on Infection. No. of Plants Infected out of 6

Series	*Urea*	*Time in Weeks*					
	per cent.	5	6	7	8	9	10
AO	0·3	2	2	2	2	3	4
AP	0·08	0	0	0	0	1	4
AQ	0·02	0	1	1	1	4	6
AV	0.15	1	2	5	6	-	-
AW	0·04	0	4	6	6	-	-
AX	None	0	2	5	5	-	-
A0-AQ	Ailsa Craig.						
AV-AX	Potentate.						

(b) The effect of potash

A parallel series of experiments was carried out to test the effect of potash on infection. In no case was any significant difference in habit noted between the plants in different series.

In the first experiment, Formula 1 was used. The results are given in Table VI. The variety was Potentate and the plants were grown in size 32 pots, using 10 pots in each experiment.

TABLE VI.

The Effect of Potash on Infection.

Series	K_2SO_4 *per cent.*	*No. infected out of 10 plants*	*No. wilting*
F	0·015	4	1
G	0·03	5	2
H	0·06	5	2
I	0·12	3	2
J	0·24	4	0

In a second experiment, using size 32 pots and the variety Potentate, the second manurial formula was used. Table VII shows the results after 5 weeks.

TABLE VII.

The Effect of Potash on Infection

Series	K_2SO_4 *per cent.*	*No. infected out of 10 plants*	*No. wilting*
AC	0·08	7	0
AD	0·15	5	2
AE	0·30	1	0
AF	0.60	5	1
AG	1·20	4	0

The results of a third experiment in which tomatoes variety Potentate were grown in 10 in. pots are given in Table VIII. There were 6 plants in each series.

TABLE VIII.

The Effect of Potash on infection. No. of Plants Infected out of 6

Series	K_2SO_4 *per cent.*	*Time in weeks* 5	6	7	8
AY	0·6	0	1	5	6
AZ	0·15	1	3	4	4
BA	None	1	3	5	5

(c) The effect of phosphate

Only one experiment was carried out using Formula 2 as the basis for varying phosphate content Size 32 pots were used and there were 10 plants in each series. The variety was Potentate. Table IX gives particulars of the treatments and results.

TABLE IX.

The Effect of Phosphate on Infection

Series	*Superphosphate per cent.*	*No. infected out of 10 plants*
K	0·05	1
L	0·1	4
M	0·2	2
N	0·4	2
O	0·8	2

From these experiments with nitrogen, potash and phosphate no clear relationship has been established between manurial treatment and infection with *Didymella*, although very wide differences in concentration have been employed. It is possible that other factors such as the direct effect of sunshine on the type of growth may also be involved.

As another method of attacking the problem, tomatoes, variety Potentate, were grown in 10 in. pots in a rich compost. When about 3 ft. high, zones were marked out on the stems by painting lines of warm vaseline half an inch apart horizontally on the stem with a fine brush. The zones were so spaced that the bottom of each was 2 inches above the top of the one below. The stems were inoculated by applying a spore suspension of *Didymella* to each zone with a soft brush. The plants were then placed in a moist chamber for 48 hours. In this way portions of stem with varying degrees of development of wood and soft tissue were exposed to infection. At the time of inoculation 50 mls. of spore suspension were poured around the base of the plants. In all, four plants were treated and there were 12 or 13 points of inoculation on each plant.

Lesions developed as follows:—

Plant 1. At heights of 11·5, 16·5, 24 and 31·5 ins.
Plant 2. At base, 4·0, 11·5, 16·5 and 26·5 ins.
Plant 3. At 9, 11·5, 21·5, and 26·5 ins.
Plant 4. At base only.

Here again there was no clear relation between the type of stem exposed to infection and the development of a lesion.

(d) Excess of manganese

Tomatoes, variety Potentate, growing in size 32 pots, were sprayed with manganese sulphate solutions at strengths of 0·75 per cent. and 0·375 per cent. with the addition of 1/2000 sulphonated lorol. Ten plants were sprayed at each strength and there were 10 controls. Two weeks later they were inoculated by pouring 50 mls. of a spore suspension on the soil. Five weeks later all the plants receiving 0·75 per cent. $MnSO_4$ were healthy, one of those receiving 0·375 per cent. had become infected, while two of the controls were infected. These differences are not considered significant.

(e) Excess of magnesium and boron

Tomatoes were sprayed twice with solutions of magnesium sulphate and borax, once just before potting into 32's and again three weeks later. Magnesium sulphate was used as a 2 per cent. solution, borax as 0·5 per cent. and 0·25 per cent. solutions. In each case sulphonated lorol was added at the rate of 1 in 2,000. Ten plants were sprayed with each solution and there were 6 controls. The borax solutions caused some marginal scorch and for the second spraying the strength of each was reduced to half. A fortnight after potting into 32 pots, the plants were inoculated by pouring 50 mls. of spore suspension on the soil. The results after 5 weeks are shown below (Table X).

TABLE X

Excess magnesium and boron.

$MgSO_4$	2 per cent. 7 infected out of 10.
Borax	0·5 per cent. and 0·25 per cent. 3 infected out of 10.
Borax	0·25 per cent. and 0.125 per cent. 7 infected out of 10.
Control	2 infected out of 6.

It would appear that the magnesium sulphate increased the susceptibility of the plants to infection, a result contrary to that obtained last year. In the case of boron, the issue is confused because a higher degree of infection was obtained with the lower concentration than the higher, the reverse of what would be expected if boron increased the susceptibility of the plant to the disease.

(2) The effect of temperature and soil moisture on survival of the fungus

Twelve hundred grammes of culture on sand and oatmeal were mixed with 16 kilos of soil and the whole divided into 4 lots which were put in 10 in. pots. The pots were then stored under different conditions. Pots A and B were kept in incubators at 20° C. and pots C and D in the refrigerator at about 5° C. Pots A and C were weighed each week and water added to keep up the water content of the soil. Pots B and D were allowed to dry out. It was intended to use the soil for inoculating plants at the end of 3 months, but unfortunately this was not possible and the soil was tested after 16 weeks. Tomatoes, variety Potentate, were potted into 32 pots, leaving about an inch at the top, which was then filled in with the soil to be tested. At the time of potting, the soil in Pot B had dried from 55 per cent. to 31 per cent. moisture content and in Pot D to 21 per cent. Ten plants were inoculated with each soil. When the plants were examined five weeks after inoculation, one plant had become infected from the soil from each of pots C and D which had been kept at 5° C.

In a further experiment, the same procedure was adopted except that pots A and B were kept at 17° C. and the soil was drier, the moisture content being 30 per cent. After seven weeks the soils were used for inoculations, the moisture content of pot B (kept at 17° C.) being then 24 per cent. and of pot D (at 5° C.) 19 per cent.

Again no plants became infected from soil kept at 17° C. while two were infected from soil kept moist at 5° C. and four from soil allowed to dry at 5° C.

These experiments suggest that the fungus survives longer at low temperatures and that a comparatively dry soil is more favourable to survival. Uncompleted experiments now in progress have tended to confirm the latter conclusion.

(3) Isolation of the fungus from the soil

Several methods are available for investigating the effect of soil conditions on the spread and survival of a fungus. One is to mix cultures with the soil and after incubating under conditions appropriate to the experiment, to use the soil for inoculating plants. The disadvantages of this method are that it needs a large number of plants and the requisite space for growing them, and that it can only be carried on during part of the year.

Other methods involve reisolation of the fungus from the soil. If the soil is first steamed and then inoculated, it speedily becomes reinfected by numerous fungi and bacteria and the problem then arises of eliminating these organisms without at the same time destroying the fungus under investigation. Furthermore there is also the danger that these invaders may compete with or even be antagonistic to the wanted fungus, so that results may be obtained that are due to effects produced by the contaminants and not by the soil conditions. In consequence repetition of the experiment may give quite different results, because the contaminants are different. Nevertheless, under some conditions this may be the only method. A more satisfactory method is to grow the fungus in pure culture in soil in flasks, but unfortunately *Didymella* does not produce spores easily in culture and inoculation of flasks of soil with cultures on solid media is not wholly satisfactory since infection is localised. Two lines of work have therefore been pursued, the search for a substance that would eliminate unwanted organisms from plates poured from the soil and attempts to induce spore production in pure culture which are detailed in section (4) below.

When plated on Dox agar, *Didymella* produces characteristic and easily recognisable colonies. This is important when large numbers of plates have to be examined and the number of colonies counted. It was decided therefore to use Dox agar as the basic medium and to investigate the effect of adding small quantities of substances known to be toxic to micro-organisms. These were salts of certain metals including copper, aluminium and nickel and certain dyestuffs with antiseptic properties.

Preliminary experiments were carried out to determine the effect of the substances on the growth of *Didymella*. In order to conserve time and materials, these were carried out in test tubes and no attempt was made to obtain exact figures as to the effect of concentration on the rate of growth since all that was needed was to know what concentration would permit the fungus to grow. The substance was then added to Dox agar and used in plating out infected soil.

Since *Didymella* appears relatively tolerant of copper, copper sulphate, copper chloride and copper acetate were used at the rate of 0·05 per cent. and 0·025 per cent. The results were variable. In some experiments *Didymella* colonies appeared on the plates although usually less in number than in the control. There was also variation in the number of contaminants and in the degree to which the copper salt was reduced to copper oxide during sterilization. To obviate this reduction, copper sulphate solutions were added in appropriate amount just before pouring the plates, but again with unsatisfactory results. Copper oxide was also used but the number of bacterial colonies in the plates remained very high.

Infected soil was also shaken up in solutions of copper sulphate instead of water when preparing the dilutions for plating, again with variable results. In one experiment, using 10 per cent. and 5 per cent. copper sulphate, both contaminating fungi and bacteria were much reduced as was also *Didymella*. In others, where the concentrations varies from 0·5 per cent. to 0·025 per cent., contamination was still very heavy.

Other salts tested were aluminium chloride, nickel nitrate and zinc sulphate. At concentrations which permitted the growth of *Didymella*, the plates remained heavily contaminated.

The dyes tested were malachite green, brilliant green, crystal violet, basic fuchsin, acid fuchsin, diphenylamine blue, auramine and rose bengal. Of these malachite green, brilliant green, crystal violet and basic fuchsin were used for plating tests, but at concentrations which allowed growth of *Didymella* heavy contamination occurred.

Rose bengal was tested in plating tests at various dilutions. A considerable reduction in the number of *Didymella* colonies occurred but contaminants were much reduced. It has since been used in certain experiments at a strength of 0·008 per cent. and it has been found that while contaminating bacteria are not eliminated, the bacteria usually form only small punctiform colonies and the spreading types which prevent the development of fungus colonies are eliminated.

(4) Sporing in pure culture

(a) Effect of temperature and light

As mentioned above, *Didymella* does not produce pycnidia readily in pure culture. Snyder and Hansen[1] have suggested that many fungi spore better when grown under natural conditions of fluctuating temperature out of doors than at more constant temperatures in incubators or on the bench in the laboratory. Accordingly cultures on Dox agar were placed in a sheltered position outdoors, a corresponding series of cultures was kept on the bench in the laboratory and another series put in the refrigerator at night and exposed to laboratory conditions by day. The experiment was repeated at monthly intervals from January to April. Black bodies resembling pycnidia and in some cases containing one-celled spores were formed in some cultures under all conditions and mature pycnidia with spores on the upper part of two cultures kept on the bench.

The observations that pycnidia were formed on the upper dry part of the agar slope suggested that thinness of medium or a high osmotic pressure in the medium might be factors of importance. Both these theories were tested but with negative results.

(b) Tomato juice

Mrs. Sheard observed that where tomato juice had been used to stimulate spore germination, pycnidia often developed on the slide. Accordingly tomato juice from stems and leaves was sterilized by filtration and added to various media, either by mixing the juice with the cooled agar or by using it to moisten the surface of the slope. The black bodies mentioned above were formed in some cases while pycnidia containing spores were formed on the dried up top of the slope in one control tube.

In preparing the tomato juice for the above experiment the material was ground up in water. It seemed possible that the resultant juice was too dilute to stimulate pycnidium production. Accordingly tomato leaves were crushed in a mortar without addition of water and the juice squeezed out. The juice was then centrifuged for 1 hour and filtered through an asbestos filter to remove colloids. The clear liquid was then treated as follows. One part was autoclaved for 30 minutes at 120° C. The remainder was sterilised by filtration and divided into three parts, each being transferred aseptically to a sterile test tube. One part was heated in the steamer at 100° C. for 30 minutes, the second heated at 50° C. for 30 minutes, and the third left untreated. These solutions

were then added to tubes of melted and cooled Hawkers' medium A[2] at the rate of 2 mls. per 15 mls. agar. In the case of the autoclaved and steamed lots precipitates were formed, but these were shaken up and added with the juice.

Pycnidia developed in the cultures receiving untreated and autoclaved juice in four weeks and later at the top of the culture in the other treatments. No pycnidia were formed in the controls. There appears therefore to be some thermostable substance in tomato juice which favours the production of pycnidia.

(c) Fumigated materials

Hansen and Snyder[3] have described a method of sterilizing materials suitable for the growth of fungi by fumigating with propylene oxide. Their method was adapted for the sterilization of tomato stems. Test tubes size 6 ins. by 1 in. containing a moistened plug of cotton wool at the bottom were sterilized in the autoclave. A piece of stem about 2 inches long taken from tomato plants about 2 feet high growing in size 32 pots was then placed in each tube, 0·1 mls. of propylene oxide run in and the tube closed with a rubber bung. The fumigant was allowed to act for 3—4 days and then the bung was replaced by a sterilized wool plug. It was found that some stems became contaminated with bacteria but that in a large number of cases they remained sterile. *Didymella* grew well on them and produced abundant pycnidia and spores.

Other materials were tested in the same way, the most successful being wheat straw. This was cut into 2 in. lengths. The leaf sheaths were removed and the straw was soaked in water overnight before fumigation. Growth was good and abundant pycnidia were formed. As wheat straw can be obtained throughout the year, it may be a useful substitute for tomato stems.

Extracts of wheat straw were also tested in the manner described in subsection (b) above, but proved relatively ineffective in inducing spore production. This method promises to be of great use in further investigations on the effect of various soil conditions on the growth and survival of *Didymella*.

References

[1] Snyder, W. C., and Hansen, H. N., Phytopathology (1947) 37, 420.

[2] Hawker, Lilian E. (1939), Ann. Bot. N.S. 3, 657.

[3] Hansen, H. N., and Snyder, W. G., Phytopathology (1947) 37, 369.

2. VIRUS DISEASES

By R. HOWLES

(a) Investigation of possible viricides

Introduction

An attempt has been made to determine if spraying tomato plants with solutions of certain chemicals will reduce infection (*a*) by killing the virus before it enters the plant ; (*b*) by increasing the turgidity of the plant and thus reducing its capacity to absorb infected liquid.[1]

The very nature of a virus suggests that it might be inactivated by substances which hydrolyse protein (proteolytic enzymes) or precipitate it (protein precipitants). Stanley[2], who has carried out considerable research on inactivation of purified preparations of tobacco-mosaic virus by chemicals found that this virus is also inactivated by oxidizing agents, and that it is sensitive to both low and also high pH.

Very few viruses are inactivated by proteolytic enzymes. Trypsin hydrolyses potato virus X and alfalfa mosaic virus. Pepsin hydrolyses potato virus X, but not tobacco mosaic, bushy stunt and tobacco necrosis viruses. Pepsin destroys potato virus X.

Protein precipitants known to inactivate tobacco mosaic virus are : 1 per cent. solutions of tannic acid, picric acid, iodine in 1 per cent. potassium iodide, mercuric chloride and lead acetate. Ammonium sulphate inactivates tobacco ringspot virus, but most plant viruses are resistant to the action of strong solutions of salts.

Oxidizing agents which inactivate tobacco mosaic virus are : 1 per cent. solutions of ferric chloride, stannic chloride, potassium permanganate, potassium dichromate, and iodine in 1 per cent. potassium iodide.

The following also inactivate virus : trisodium phosphate, sod um benzoate, sodium dodecyl sulphate and 2 per cent. lysol. The action of trisodium phosphate is possibly a pH effect. Urea

inactivates tobacco-mosaic, potato X, tomato bushy stunt and tobacco necrosis viruses—the inactivation is increased by the presence of alkali. Kuntz and Walker[3] discovered that extracts of leaves of spinach, garden beet and sugar beet inactivate tobacco-mosaic virus in the juice of tobacco and that spinach inactivates cucumber-mosaic virus in plant juice. Storey[4] found that the virus of streak disease of maize was inactivated in vitro by exposure to light in the presence of methylene blue and oxygen.

In vivo inactivation of virus has been reported by Stoddard[5]. Peach buds suffering from X-disease were cured by immersing them in solutions of quinhydrone, urea and sodium thiosulphate.

Experimental

Tomato plants potted singly in 3 inch pots were used.

Prior to spraying, the plants were given 100 mls. of water per pot either every other day or every day according to age and temperature.

Spraying was performed by means of a 5 hole, 25 ml. syringe. Where the object was to kill the virus before it entered the plant, the three terminal leaflets of the fourth foliage leaf from the base of the stem were sprayed at the six foliage leaf stage. 5 ml. per plant were given on each of two successive days, the second spraying being one day before inoculation. It was decided to use 1 per cent. anhydrous solutes, but preliminary experiments were carried out to determine if each solution was sufficiently dilute to cause no injury. Where the object was to increase the turgidity of the plant the whole shoot system was sprayed with 2 per cent. potassium sulphate several times from the three foliage leaf stage until inoculation, 12·5 ml. per plant being given each time. 2 per cent. potassium sulphate is not harmful to the plant; it darkens the colour. One day before inoculation the potassium sulphate was rinsed off the plant with distilled water. In both series of experiments spray was kept off the soil by means of a jaconet disc. A similar disc was placed round each control. The periphery of the top of the soil was sprinkled with one volume of Paris green in 50 volumes of oatmeal or dried blood to keep woodlice from gnawing the base of the stem while the disc was round it. The disc was only in position during the period between spraying and inoculation.

TABLE I

The Effect of Sprays on the Entry of Mosaic Virus into the Tomato Plant.

Treatments	Sprayed Plants		Controls	
	Mottling Absent	Definite Mottling Present	Mottling Absent	Definite Mottling Present
(a) Experiments:				
Spray.				
1% tannic acid	6	2	2	7
1% „ „	8	2	6	4
Fresh 1% tannic acid	10	0	4	6
1% tannic acid	8	2	4	6
0·5% thiazamide	5	4	2	7
„ „	7	3	6	4
Old 0·5% thiazamide	5	4	4	6
Fresh 0·5% thiazamide	5	5	4	6
0·43% trisodium phosphate	3	6	2	7
0·05% „ „	3	7	4	6
Same solution	5	5	5	5
Saturated quinhydrone	3	7	5	5
Fresh one-tenth saturated quinhydrone ...	4	6	4	6
0·2% sodium thiosulphate	5	5	5	5
Same solution	4	6	3	7
Solution of urea, 0·1% and of potassium bicarbonate, 0·1%	7	3	5	5
Same solution	7	3	3	7
„ „	7	3	5	5
„ „	7	3	5	5
(b) Experiments:				
Inoculated April 5th, 1948	5	5	6	4
„ April 29th, 1948	5	5	4	6
„ June 28th, 1948	6	4	5	5
„ July 23rd, 1948	3	7	5	5

The plants were inoculated at the six foliage leaf stage. The three terminal leaflets of the fourth foliage leaf from the base of the stem were stroked twice with cotton wool soaked in tomato aucuba mosaic virus solution. The virus solution was prepared by grinding *Nicotiana tabacum* leaf infected with the virus in distilled water, filtering the liquid through cotton wool, rinsing in each case with distilled water the pestle, mortar, funnel and cotton wool into the cylinder and making up with distilled water to 200 ml. per gm. of leaf. For each (a) experiment the virus solution was divided into equal parts equal in number to all the groups. One part and a piece of cotton wool were used for inoculating all the plants of only one group. All the pieces of cotton wool used in each experiment were of equal size. In both series of experiments from the commencement of inoculation two plants of each group were inoculated and this was repeated until all the plants had been inoculated.

In an experiment there were 10 plants for the same spray treatment and ten controls. It was intended to perform two experiments and a third if there was an increase in incubation time.

In determining the effect the head of the plant was examined for symptoms of infection.

Results

These are given in Table 1. 0·43 per cent. tri-sodium phosphate caused injury within a few days. Injury from a saturated quin-hydrone appeared a few days later. Injury occurs in sunny, hot weather, but not in dull, cool weather. None of the other concentrations were injurious. 1 per cent. sodium thiosulphate caused slight injury. The solution of urea, 1 per cent. and of potassium bicarbonate 1 per cent. was highly injurious. Stock 0·5 per cent. thiazamide and that in the beaker were shaken just before use. Tannic acid solution, thiazamide suspension and quinhydrone solution alter.

Conclusions

1 per cent. tannic acid spray appears to be an efficient agent for preventing the spread of mosaic infection by mechanical means. As the solution ages it becomes less effective. Solution of urea, 0·1 per cent., and of potassium bicarbonate, 0·1 per cent., is suitable to a less extent. None of the other sprays was effective in reducing the incubation period.

In cell sap the high pH of trisodium phosphate may be neutralized, destroying its toxic property.

References

[1] Howles, R., Rep. Exp. Res. Sta., Cheshunt, 1947, 33, 22-28.

[2] Stanley, W. M., Phytopath., 1935, 25, 899-921.

[3] Kuntz, J. E., and Walker, J. C., Phytopath., 1947, 37, 561-579.

[4] Storey, H. H., Ann. Appl. Biol., 1934, 21, 588-589.

[5] Stoddard, E. M., Phytopath., 1942, 32, 17 and 1944, 34, 1011.

(b) The effect of heat treatment on mosaic disease of *Solanum capsicastrum*

R. HOWLES

Introduction

The beneficial effect of heat treatment was reported by Kunkel[1],[2]. Peach yellows was cured by incubating active trees in pots in a hot room held at 35° C., and dormant trees by immersion for about ten minutes in water at 50° C. The trees were not seriously injured by these treatments. " Yellows " in periwinkle plants was cured by treatment in a hot room at 40° C. for two weeks and in *Nicotiana rustica* by treatment at 40° C. for three weeks.

No one seems to have shown that a virus in vivo can be destroyed directly by heat and it is doubtful if this can be done. In the case of tomato plants inoculated with mild tobacco mosaic virus before being placed under differential temperature conditions, the resulting degree of mottling is most severe at about 100° F.[3] This does not necessarily mean that the virus is destroyed at higher temperatures. It may only multiply more slowly. In the case of the work mentioned in the first paragraph, destruction of the virus may have been caused by the plant itself.

General procedure

S. capsicastrum plants in 3 in. pots and at the four foliage leaf stage at the time of inoculation were used.

All plants were watered equally. Each heat treated plant received additional water immediately before each heat treatment. In the experiments, where the period of continuous heat treatment was prolonged, the potted plants were standing in a tray of water while in the oven.

All the foliage leaves of each plant were stroked once with cotton wool soaked in mild tobacco mosaic virus solution. From October to February the rubbing was done very gently. The virus solution was prepared by grinding *Nicotiana tabacum* leaf infected with the virus in water and diluting after filtering to the desired concentration. Carborundum dusted uniformly over all the plants was used as an abrasive. The foliage was rinsed with distilled water.

Heat treatment was carried out (in the dark) in an electric oven. Continuous records of temperature were made with a standardised thermograph. The temperature variation in the oven was $\pm 1°$ F. The heat treatment did not harm the plant, although growth was retarded slightly and the colour made slightly paler.

Experiments

I. No heat treatment until the plants showed infection

Method

Heat treatment lasted $7\frac{1}{2}$ hours, namely $1\frac{1}{2}$ hours on each of five consecutive days. The temperature was 115° F. There was no heat treatment until all the plants of the experiment showed the presence of infection. Three experiments were carried out. In the first experiment the number of plants was 24 and there were 200 ml. of virus solution per gm. of leaf. In the second experiment the number of plants was 36 ; the inoculum was stronger—50 ml. of virus solution per gm. of leaf —to obtain a greater heat treatment effect. In the last experiment—12 plants—the inoculum was again stronger ; there were $33\frac{1}{3}$ ml. of virus solution per gm. of leaf.

Results

In the first experiment virus symptoms disappeared on each plant at about the same time. In the second the heat treated plants recovered a normal appearance slightly earlier. The final condition of the plants in the third experiment is given in Table I.

TABLE I.

The Effect of Heat Treatment on Susceptibility to Tobacco Mosaic Virus

Experiment.		*No. of plants.*		
		Alive with no necrosis.	*Alive with necrosis.*	*Dead.*
I 3	Heat treated plants	1	0	5
	Controls	4	0	2
II b1	Heat treated plants	2	0	9
	Controls	11	0	0
II b2	Heat treated plants	6	3	2
	Controls	5	6	0

Conclusions.

It was concluded that this method would indicate no reduction in infection by heat treatment. There was an indication that heat treatment under these conditions makes the plant more susceptible to this disease, assuming that it does not increase the rate of multiplication of the virus particles.

II. First heat treatment shortly after inoculation

In this series of experiments treatment began shortly after inoculation.

(a) Short heat treatment

The first heat treatment was applied on the day following inoculation. The heat treatment was as in Series I. The number of plants in the experiment was 36. There were 100 ml. of virus solution per gm. of leaf. Heat treatment delayed the appearance of symptoms of infection. At one time the number of plants showing the presence of disease was: Heat treated plants, 5 out of 18 ; controls, 18. The 36 plants died from the infection.

It was considered that longer heat treatment might result in less maximum infection in the heat treated plants.

(b) Long heat treatment

Method

Two experiments were attempted. In each the number of plants was 22. The plants were inoculated at 10—10.22 a.m. and the first heat treatment began that evening. Heat treatment

lasted for 60½ hours, covering four consecutive days, from 7 p.m. to 9 a.m., and then from 5.30 p.m. to 9 a.m. The temperature was 105° F. There were 200 ml. of virus solution per gm. of leaf in each case.

Results and conclusions

The results are given in Table I. The results for the first experiment indicate the final condition of the plants. In each experiment all 22 plants showed evidence of infection.

The indication that heat treatment makes the plant more susceptible to tobacco mosaic virus was confirmed.

In the next two groups of experiments the virus concentration in the inoculum was small.

(c) Long heat treatment, small virus concentration

Method and results

The method was as in the II b experiments.

A series of 10 experiments were carried out in which the amount of virus solution per gm. of leaf varied from 300—1,600 ml. The data of two typical experiments are illustrated in Figs. 1 and 2. It was necessary to use plants at the same foliage leaf stage since susceptibility varies with age, old plants being least susceptible. Hot weather seems to reduce the amount of infection.

(d) Short heat treatment, small virus concentration

It is possible that in heat treated plants an increase in susceptibility may preponderate over any destruction of virus and hence it was decided to try shorter heat treatment, keeping the virus concentration small. Three experiments have been carried out. The heat treatment began 9 hours after inoculation and was 15 hours from 7 p.m. to 10 a.m. The temperature was 105° F. and the results are given in Table II. Heat treatment produced no reduction in infection.

TABLE II.

The Effect of 15 hours Heat Treatment at 105° F. on the Development of Tobacco Mosaic Virus

Experiment	*Amount of virus solution in ml. per gm. of leaf*	*Plants inoculated on*	*Date*	*Number of plants out of 11 which had developed signs of infection.*	
				Heat treated plants	*Controls*
II c1	800	3/11/48	24/11/48	1	3
II c2	200	22/12/48	1/1/49	8	6
II c3	200	31/12/48	7/1/49	5	6

Conclusions. Sections II c and II d

1. There is some evidence for destruction of virus by long heat treatment. In all the experiments, 21 days from inoculation, the number of heat treated plants which had been infected was 62, of controls 76 ; heat treatment produced 18·4 per cent. decrease. Heat treatment reduced greatly the number of lesions, but owing to infected leaves falling off the plants it was impossible to obtain the maximum number of lesions. In summer the lesions cannot be counted satisfactorily.

2. The heat treated plants recovered quicker from the disease. This may not be entirely a direct heat effect (recovery would be quicker from less systemic not local infection). In a heat treated leaf there may be either greater rate of virus multiplication or more destruction, causing the leaf to fall off the plant sooner. This is similar to mild tobacco masaic virus in *Nicotiana glutinosa*, where the virus kills the tissue surrounding the point of inoculation and so prevents further spreading of the disease.

III. Hot water treatment

It was intended to try the hot water treatment, if the plants would stand it, in order to subject plants to a higher temperature without desiccation. However, half an hour in hot water at 122° F. (50° C.) severely injured *S. capsicastrum* plants at the four foliage leaf stage. The plants were completely immersed in water in a metal tray and after heat treatment were repotted. The plants were held down by a light perforated metal plate and the water in the tray had been brought to 122° F. before immersion of the plants.

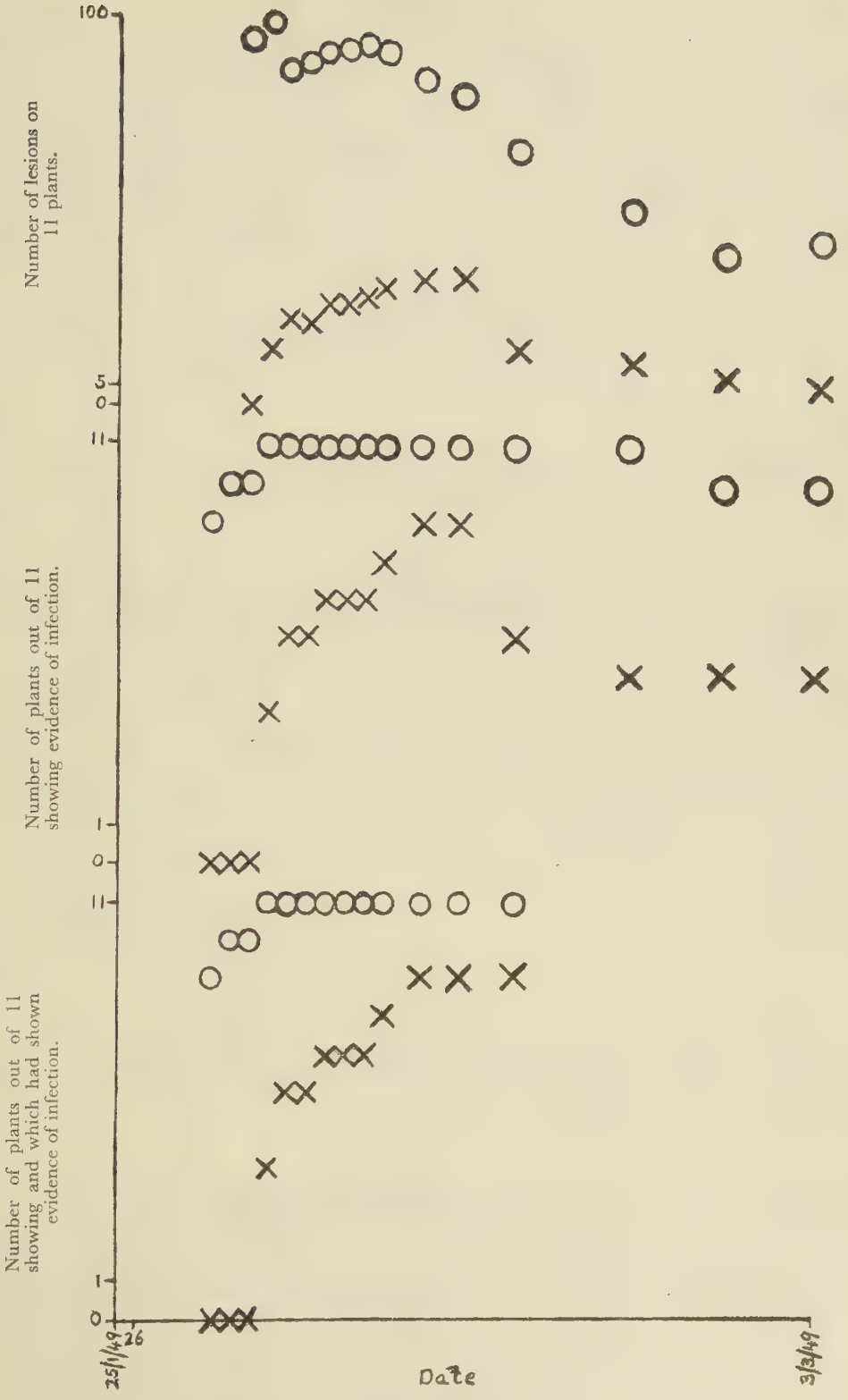


FIG. 1.—Effect of heat treatment on tobacco mosaic virus infection.
1,000 ml. of virus solution per gm. of leaf.
× = heat-treated plant. O = control.

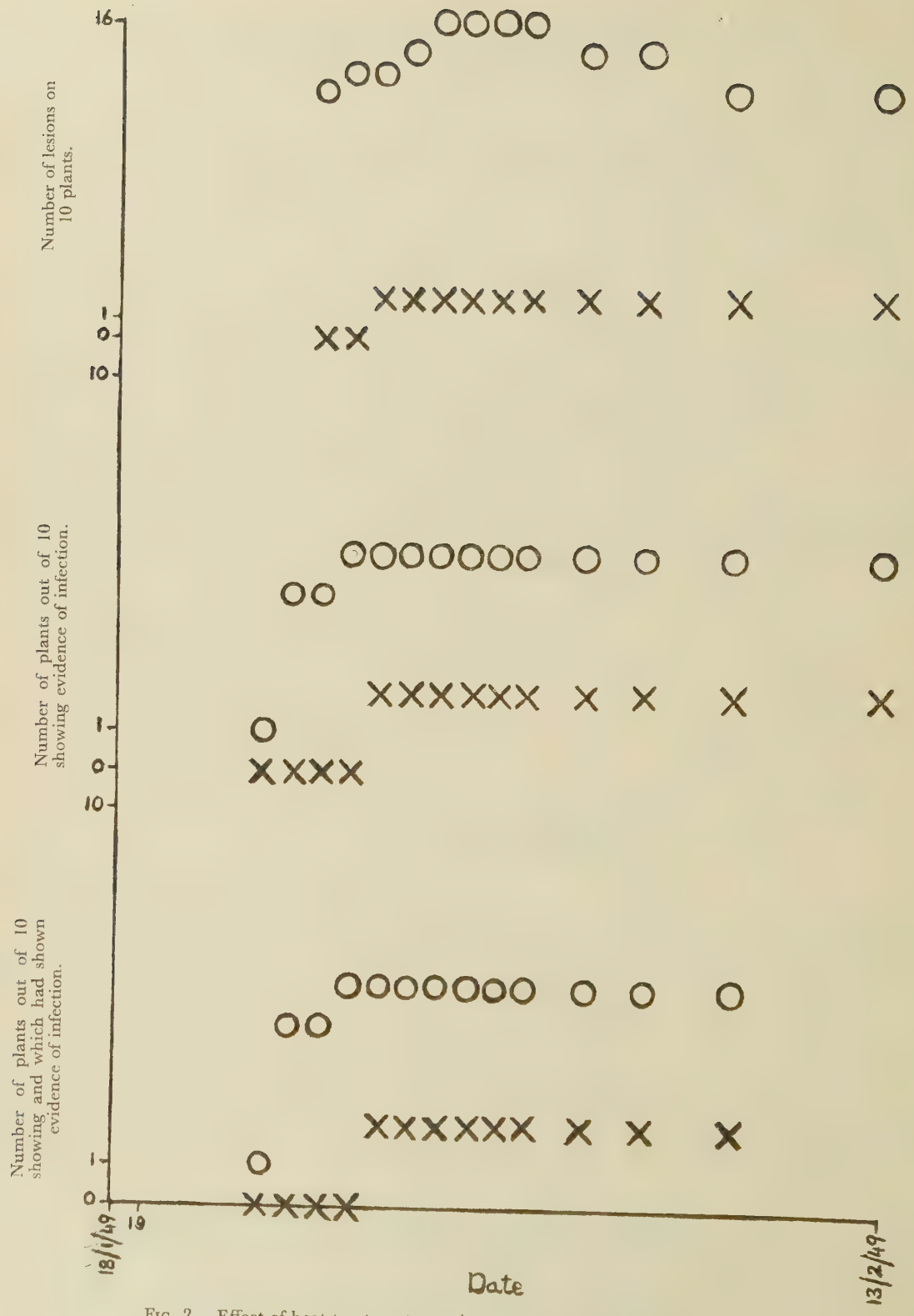


Fig. 2.—Effect of heat treatment on tobacco mosaic virus infection.
1,000 ml. of virus solution per gm. of leaf.
10 heat-treated plants, 11 controls.
× = heat-treated plant. O = control.

Summary

Experiments were performed to determine the effect of heat treatment on *Solanum capsicastrum* plants inoculated with tobacco mosaic virus. The following general conclusions were obtained.

1. Prolonged heat treatment—60 hours at 105° F.—of plants shortly after inoculation with a weak virus solution resulted in fewer plants showing symptoms of infection than in the controls. Fewer lesions developed on the heat treated plants but it was not possible to obtain the maximum number owing to infected leaves falling off the plants. The heat treated plants became visibly free from the disease quicker than the controls. The heat treatment had no harmful effect on the plant.
2. Heat treatment makes the plant more susceptible to the disease.
3. Hot water treatment severely injured the plants.

References

[1] Kunkel, L. O., Phytopath., 1936, 26, 809-830

[2] ——— Amer. Journ. Bot., 1941, 28, 761-769.

[3] Howles, R., Rep. Exp. Res. Sta., Cheshunt, 1947, 33, 22-28.

3. INVESTIGATIONS ON MICROBIAL ANTAGONISM AND ANTIBIOTIC SUBSTANCES

By E. GROSSBARD

Penicillium patulum and its possible effect on the control of damping off of tomato seedlings.

In previous reports [1], [2] an account was given of attempts to utilise the antagonistic action of *P. patulum* on *Phytophthora parasitica* for the control of damping off of tomato seedlings. Although past results have not been consistent, there were indications that under some conditions, not fully understood, the spread of damping off from a centre of infection was inhibited to some extent. The investigation was continued in 1948.

The technique employed was similar to that used previously. The following modifications were introduced.

1. Mollassed sugar beet pulp was included in this trial as a source of carbohydrate, for it gave very good results in in-vitro experiments for the production of an antibiotic substance in sterilised soil.
2. Half the number of boxes were inoculated with *P. patulum* on sand-oatmeal medium, the remainder being used as controls.
3. Cultures of *P. parasitica* mixed with small, weighed quantities of soil, were introduced at the ends of the boxes (14 ins. by 4 ins.).
4. Five different composts were used:
    1. Soil only.
    2. Soil plus 2·5 per cent. glucose
    3. Soil plus 2·5 per cent. mollassed sugar beet pulp.
    4. Soil plus 2·5 per cent. straw.
    5. Soil plus 5 per cent. straw.
    6. Soil plus 2·5 per cent. straw plus 2·5 per cent. glucose.

Glucose was applied by spraying the soil at intervals with a glucose solution. Glucose is quickly destroyed when added to soil and this method of application had to be used. 30 seeds per box were sown.

Results

In both the controls and treated boxes germination was 96 per cent. and the plants developed in the normal manner. Four weeks after emergence, however, only a small number of seedlings had damped off in the boxes of soil infected with *P. parasitica*, although in the small portion of soil where the inoculum was actually placed, disease incidence was 98 per cent. Although this showed that the culture of *P. parasitica* was virulent, the fungus apparently had hardly spread through the soil, although introduced eight weeks previously. There was no significant difference between treated boxes and the controls. It was therefore decided to re-sow all boxes. To ascertain if the low incidence of damping off was due to the slow rate of spread of the fungus and to no other factor the inoculum containing the pathogen was evenly mixed with the entire compost in one box in each set of six replicates.

The results are set out in Table I and refer to the localised inoculation set only.

TABLE I

MEAN PERCENTAGE OF SEEDLINGS DAMPED OFF EIGHT WEEKS AFTER EMERGENCE.
LOCALISED INOCULATION SET.

Substratum	Inoculated with *P. patulum*	Not Inoculated with *P. patulum*
1. Soil	13	7
2. „ and 2·5% glucose	8	7
3. „ „ 2·5% sugar beet pulp	1*	11
4. „ „ 2·5% straw	7	3
5. „ „ 5·0% „	21	10
6. „ „ 2·5% „ and 2·5% glucose ...	24	14

*Damping-off occurred only in one box out of five.

The final figures showed that the incidence of damping off was considerable in boxes where the inoculum was mixed evenly with the entire compost. In boxes with a localised inoculation, damping off was more severe than before but still comparatively low, indicating a very slow growth rate of *Phytophthora* through the soil, under the conditions of this experiment. As in previous years, the results of the five replicates in each set varied considerably.

The figures in Table I showed that one treatment only gave clearly defined and positive results, namely the incorporation of 2·5 per cent. of molassed sugar beet pulp with soil inoculated with *P. patulum*. In four out of five boxes of this set no damping off at all was observed. In the box where the inoculum was evenly mixed with the entire compost, disease incidence was 19 per cent. as compared with 63 per cent. in controls of untreated soil infected with *P. parasitica*. All other results were negative.

The antibiotic activity of cultures of Penicillium patulum on several organic materials

The search for plant materials that could be used to induce the production of antibiotic substances in the soil was continued. Cultures of *P. patulum* on rye grass, timothy grass, red clover and a standard green manuring grass mixture were compared with wheat straw cultures. The technique was described in the Annual Report for 1947. Results set out in Table II show that timothy grass was somewhat more efficient than wheat straw. An antibiotic substance was formed on red clover three days after inoculation but when the metabolic solution was tested again after fourteen days no antibiotic could be detected.

Leguminous plants gave poor results in last year's experiments when sainfoin and lucerne were tested. West and Hildebrand[3] working on the control of strawberry root-rot by organic manuring with clover and soya beans, reported that while the manuring with soya beans, which contain a high percentage of carbohydrate, controlled the disease the manuring with clover was quite ineffective. There may be a correlation between the factors which render some legumes unsuitable media for antibiotic production by *P. patulum* and those responsible for their failure to control strawberry root rot when incorporated with the soil.

TABLE II

A COMPARISON OF THE ANTIBIOTIC ACTIVITY OF THE CULTURE FLUID OF P. PATULUM GROWING ON SEVERAL PLANT MATERIALS WITH THAT OF WHEAT STRAW CULTURES.
TEST ORGANISM : B. MYCOIDES, CYLINDER PLATE METHOD.

Substratum	Inhibition	% Activity as compared with Wheat Straw Cultures
Wheat Straw	Complete	100
Timothy Grass	Complete	123·0
Red Clover*	Activity Lost	—
Rye Grass	Complete	82·5
Green Manuring	Complete	91·5
Grass Mixture		

*Three days after inoculation inhibition was complete and activity 78%. Results with red clover varied considerably when repeating experiments with identical material.

The production of an antibiotic substance by Penicillium patulum in autoclaved, partially sterilised and re-contaminated sterilised soil

Autoclaved soil

The experiments on the production of an antibiotic substance in autoclaved soil by *P. patulum*, reported in 1947, were continued. A more detailed account of the current investigations, giving experimental details and final figures will shortly be published elsewhere.

The investigations were as follows :—

The comparative efficiency of various sources of carbohydrate and the minimum and optimum rates of application to the soil were determined, the substances tested being glucose, sugar beet pulp, timothy grass and straw.

Soil was mixed in varying proportions with the materials concerned, water being added in sufficient quantity to just saturate the mixture. The soils were autoclaved, inoculated with *P. patulum* and incubated for fourteen days. The cultures were centrifuged and the extracted liquid assayed for antibiotic activity. Results confirmed the observations made last year. The extracts from soils containing glucose showed the greatest activity against the test organisms, followed by sugar beet pulp, timothy grass and wheat straw in order of efficiency.

Extracts from soils to which 0·5 per cent. glucose by weight of oven-dried soil (0·3 per cent. of total weight) were added, inhibited completely the growth of the test organism *B. mycoides*. Waksman[4] stated that soil, as such, is too poor a medium for antibiotic production. This work, however, shows that only a comparatively small addition of carbohydrate to a sterile soil makes it a suitable medium for the production of a water soluble inhibitory agent by *P. patulum*. These experiments were carried out with a fertile top soil and also with subsoil.

Partially sterilised soil

Results reported so far refer to autoclaved soil only, namely soil that was completely sterile. As it is impossible to use soil of this type for practical work, trials were made with soil that had been steamed once for 30 minutes at 100° C., namely soil that was only partially sterile. Glucose and sugar beet pulp were used as carbohydrate sources in these preliminary tests. The results showed that an antibiotic substance, extractable by the methods described in connection with autoclaved soil, was formed readily in a partially sterilised soil.

Re-contaminated sterilised soil

An attempt was made to determine if an antibiotic had been formed in the soil used for the damping off experiment. This soil was partially sterilised at the start of the experiment but had quickly become contaminated with the general microflora of the glasshouses in which it was incubated. Samples were taken from the soils inoculated with *P. patulum* three weeks after inoculation, as well as from soils into which this fungus had not been introduced. The samples were shaken up with distilled water, the liquid removed by centrifuging and tested for antibiotic activity against *B. mycoides* and *B. coli*. Results were negative with one exception. Extracts from two out of six samples of soils inoculated with *P. patulum* and containing 2·5 per cent. of sugar beet pulp showed weak partial inhibition of *B. mycoides*. When, however, samples were taken again one week later, this effect was not observed. It is interesting to note that these samples were taken from the same soils in which an inhibition of the spread of damping off had been observed.

It has been reported that an antibiotic substance was produced by *P. patulum* in autoclaved and partially sterilised soil when a source of carbohydrate such as glucose, sugar beet pulp, etc., was added. This substance was extracted easily with water. The soils used in the damping off experiments contained various sources of carbohydrate but the extracts, with one exception, showed no inhibitive action. These negative results must not, however, lead to the conclusion that an antibiotic substance had not been formed at any stage during these experiments. It is quite possible that the inhibitory agent was produced, but in a very low concentration, owing to the keen competition with other micro-organisms for the supply of carbohydrate. It may be assumed that owing to its low concentration the substance was entirely adsorbed on the soil colloids and that the extraction methods used did not remove it from the soil. It is well known that antibiotics are easily adsorbed on charcoal, norrit and other similar materials. It is probable that soil colloids may behave similarly in this respect. It is, however, also possible that the substance was destroyed by enzymes in the soil. Preliminary investigations were also made on soils which had never been sterilised. Glucose, sugar beet pulp and straw were added. Half of these soils were inoculated with *P. patulum*, the other half were left as a control. Results are not yet available.

It was interesting to observe that aqueous extracts of soils irrespective of the presence of *P. patulum* exerted different effects on the growth of the three test organisms, *B. coli*, *B. mycoides*, and *B. phytophthorum* (*B. carotovorum*). On plates with *B. coli* narrow zones (11-13 mm.) of weak partial inhibition were noted in a few instances, suggesting that the soil solution as such may contain substances slightly inhibitive to the growth of *B. coli*. With *B. mycoides* the effect was reversed, for zones of stimulated growth (25-30 mm.) were observed. This growth stimulation may be due to probiotic substances of microbial origin or to the nutrients contained in the soil solution. These nutrients may have been responsible for the denser growth in the areas into which the solution had diffused on the assay plates containing Difco beef extract. Support was given to the view that growth stimulation may be due to factors of nutrition by the observation that extracts from sterilised straw or grass gave similar zones of stimulation. Whatever the cause of this effect, it is a specific one. It is absent on test plates with *B. phytophthorum*.

The retention of an antibiotic substance by the soil

The possibility of adsorption of part or whole of the antibiotic substance formed in the soil was mentioned above. The following experiments may provide some support for this assumption of adsorption.

200 g. of soil were mixed with 4 per cent. of straw by weight of oven-dried soil or 2 per cent. of total weight, water to saturation point being added. The mixture was autoclaved and inoculated with *P. patulum*. After incubation the culture which had grown very well, was centrifuged and the resulting liquid assayed against *B. mycoides*. No inhibition was observed. When, however, the same mixture was autoclaved but not inoculated, centrifuged and the resulting liquid inoculated with *P. patulum*, an antibiotic substance was easily detected in the metabolic fluid (see Fig. 1). Although the results of the first experiment suggested that the quantity of straw added was below the minimum required for antibiotic production, the results of the second trial showed that this quantity was sufficient when the fungus was cultivated on the extract of the same but not previously inoculated soil. A possible explanation is that the antibiotic substance had been formed in the first case, i.e., directly in the soil culture, but owing to the small quantity of straw, it was present only in low concentrations, and was thus entirely adsorbed on the soil colloids. It could not be removed by the extracting methods used here. Experiments are now in progress to discover more efficient methods of extraction that would remove the antibiotic adsorbed by the soil. It is hoped that such methods may help in demonstrating the presence of antibiotics in unsterilised soil. Whether an antibiotic in the adsorbed state would exert any effect on the microbial population of the soil also requires investigation.

Preliminary trials on the persistence of the antibiotic substance in the soil

In the report for 1947 an account was given of the persistence of the antibiotic substance produced in wheat straw cultures of *P. patulum*. It was shown there that activity is retained for four months even under septic conditions. Experiments were made to see if the substance would persist in soils where production had been already demonstrated, after these soils had been invaded by organisms of the general microflora. To ascertain if the inhibitory agent was present, cultures of *P. patulum* on sterile soil containing varying quantities of either glucose, sugar beet pulp, timothy grass or straw, were centrifuged and the liquid tested. The first centrifuging did not remove the antibiotic entirely. Three leachings were carried out on a sample on the same day. The last leaching still showed the presence of a very active antibiotic. The soils were left exposed to contamination. Samples were taken at intervals, shaken up with distilled water and centrifuged. Preliminary results showed that activity was retained for at least one week but not for four weeks. The exact period of time during which the inhibiting agent persisted has not yet been determined.

A second experiment is at present in progress in which flasks containing cultures of *P. patulum*, as described above, were left to incubate for two weeks. The soils were then removed from the flasks and left exposed to the air in open containers. At weekly intervals batches of five were removed and centrifuged. The results so far obtained appear to agree with those of the above trial.

The influence of various fertilisers on the antibiotic activity of wheat-straw cultures of P. patulum.

For antibiotic production in sterilised soil by *P. patulum*, the incorporation of material of a high carbohydrate content is necessary. Plants growing for any length of time in these soils soon become starved. To overcome this the addition of fertilisers is necessary. Preliminary experiments, however, have suggested that the addition of certain sources of nitrogen reduced antibiotic activity. A more detailed investigation was carried out this year, using sodium nitrate, potassium nitrate, urea, sulphate

of ammonia, superphosphate, sodium nitrate plus superphosphate, and potassium nitrate plus superphosphate. The standard was a wheat-straw culture of *P. patulum* of the same age to which no fertiliser was added. The fertilisers were added in quantities sufficient to add 1 per cent nitrogen or 1·5 per cent. P_2O_5 respectively to the standard wheat-straw medium. The results are tabulated in Table III.

TABLE III

The Reduction of the Antibiotic Activity of Straw-Water Cultures of P. patulum brought about by the Addition of Fertilisers.

Test Organism : B. mycoides.

Results from one typical Experiment.

Fertiliser Added	pH		Percentage Reduction in Antibiotic Activity after 14 Days
	Before	After 14 Days' Incubation	
Sodium Nitrate	6·0	6·5	20·3
Potassium Nitrate	6·2	6·5	25·1
Sulphate of Ammonia ...	5·5	4·5	50·4
Urea	6·8	7·1	38·5
Superphosphate	4·3	4·2	13·0
Superphosphate with Sodium Nitrate ...	4·5	6·3	54·9
Superphosphate with Potassium Nitrate ...	4·3	5·9	53·3

The figures in Table III showed that all nitrogenous fertilisers reduced the antibiotic activity as compared with the standard. The degree of suppression varied with the source of nitrogen, sodium nitrate and potassium nitrate showing the least reduction. The addition of nitrogen also affected the persistence of the inhibiting agent. Assays made nine weeks after inoculation showed that activity was lost in all nitrogen cultures. Those containing sodium nitrate retained activity for the longest period of time. The degree of reduction in activity and persistence caused by sodium nitrate was not so large that this loss might not be offset by the beneficial action of the nitrogenous fertiliser in reducing carbohydrate induced nitrogen starvation of the plants. Urea and sulphate of ammonia were quite unsuitable. Superphosphate reduced activity to a small extent, but it appeared to arrest the destruction of the inhibitory agent, with the result that twelve weeks after inoculation the activity in cultures containing superphosphate exceeded that of the standards.

Although the results of the four experiments which were made varied quantitatively, this effect of superphosphate on the persistence of the antibiotic was observed throughout. In two experiments (in the first week of growth) superphosphate either did not affect activity at all or even stimulated it.

A mixture of sodium nitrate and superphosphate or of potassium nitrate and superphosphate greatly reduced activity. The change brought about in the pH of the media by adding the fertilisers did not seem to affect the activity.

The experiments are at present being repeated on soil straw culture. Preliminary results suggested a similar behaviour of soil straw cultures as compared with wheat-straw cultures.

Blair[5], Garrett[6], reported that the spread of soil borne fungi was arrested or the disease incidence reduced, when organic manures of a high carbohydrate but low nitrogen content were added to the soil. A correlation between these reports and the above observations is suggested.

The production of an antibiotic substance by Aspergillus terreus.

Soil containing 4 per cent. glucose and extracts made from sterile soil containing glucose or sugar beet pulp were inoculated with *A. terreus*. An antibiotic substance was produced, but the test organism *B. mycoides* proved less sensitive to this antibiotic than to the substance produced by *P. patulum*; *B. coli* and *B. phytophthorum* were not sensitive at all.

Summary.

1. Experiments on the control of damping off in soils containing various sources of carbohydrate and inoculated with *P. patulum* were continued. The only effective treatment was that in which sugar beet pulp was incorporated with soil infected with *P. patulum*. All other treatments were either ineffective or stimulated the disease.

2. It was shown that timothy grass was a suitable substance for antibiotic production.

3. Investigations were continued on the production of an antibiotic substance in autoclaved soil. The addition of glucose gave the best results.

4. Preliminary results showed that an antibiotic could be formed in partially sterilised soil.

5. The effect of various fertilisers on antibiotic production on wheat straw cultures of *P. patulum* were examined. All fertilisers reduced antibiotic activity to a varying degree. Superphosphate showed the least degree of suppression and seemed to prolong the persistence of the antibiotic. Sodium nitrate and superphosphate may be added to the cultures separately without unduly reducing antibiotic activity.

6. *Aspergillus terreus.* was shown to produce an antibiotic substance in autoclaved soil.

This work has been carried out with a grant from the Agricultural Research Council.

We are greatly indebted to :—

Professor J. T. Jenkin for the supply of a sample of timothy grass.

Mr. R. C. Warren for the supply of finely ground straw.

Messrs. R. A. Engledow and L. E. Edney of the National Agricultural Advisory Service for the supply of rye grass and other plant materials used in these experiments.

The British Sugar Corporation, Ltd., for a sample of plain and molassed sugar beet pulp.

References

[1] Grossbard, E., Rep. Exp. Res. Sta. Cheshunt, 1946, 32, 41.

[2] Grossbard, E., *Ibid.*, 1947, 33, 29.

[3] West, P. M., and Hildebrand, A. A., Canad. J. Res. (C), 1941, 19, 199.

[4] Waksman, S. A., Biol. Rev. 1948, 23, 452.

[5] Blair, I. D., Ann. Appl. Biol. 1943, 30, 118.

[6] Garrett, S. D., Ann. Appl. Biol. 1938, 25, 742.

III. ANIMAL PESTS

E. R. SPEYER and W. J. PARR

1. TOMATO LEAF—MINER (Liriomyza solani Hering)

Prevalence of the Agromyzid fly, *Liriomyza solani* Her. during the growing season of 1948 in glasshouses of the Lea Valley, and an infestation of considerable severity during spring and early summer in a glasshouse at the Cheshunt station, have provided material from which it has been possible to obtain more accurate information upon the biology of this insect, as compared with that previously published (Speyer 1938 and 1944).

Observations upon the effect of certain insecticides which have of late been employed on commercial nurseries in attempts to bring infestations under control have also been recorded.

Dr. F. van Emden, Commonwealth Institute of Entomology, has again given his valuable assistance in determining the species of Liriomyza involved in these infestations. It would now appear that all the material collected in glasshouses of the Lea Valley since and including that first obtained at Edmonton in 1935 is referable to the one species *L. solani* Her., and that the species *L. strigata* Meigen has not occurred on glasshouse plants in the British or the Channel Islands.

When the late F. W. Edwards determined the specimens from Edmonton as *L. solani*, he accidentally attributed the authorship of this species to Macquart, whereas the insect was first described by Hering in 1927 : the error has found its way into probably all the literature published in England since 1935.

The larval mines of *L. solani* Her., have previously been supposed only to occur in the foliage of tomato and some other Solanaceous plants, and it is therefore remarkable that they should have been found rather infrequently in that of cucumber, and very rarely in that of lettuce, though always in glasshouses in which tomatoes have been grown at the same time or shortly beforehand.

This once more raises the question as to whether two separate species may be present and all the material collected has now been submitted, on the advice of Dr. van Emden, to Dr. J. E. Collin who has very kindly offered to examine especially the structure of the puparia, which may show greater differences between species than those exhibited by mature insects.

1. **The adult flies**—general appearance and habits.

The ground colour of the flies is dark brown or black ; the very large eyes are black (reddish in immature specimens), the antennal arista dark : the remainder of the head, a large dorsal area on the posterior portion of the thorax, the sides and ventral surface of thorax and abdomen, and the dorsal sutures between the abdominal segments are yellow. The wings which, in both sexes, have an expanse of about one-sixth inch are transparent but highly irridescent.

The males are usually rather smaller than the females, the former measuring about one-sixteenth inch, and the latter about one-twelfth inch in length.

The sexes are readily separable, under comparitively low magnification with the binocular microscope, through differences in the shape of the abdominal extremity : in the male this is rounded and partially encircled by a dark area, while in the female the posterior segment is entirely dark, elongate and tapers somewhat to its abruptly truncate end.

The flies were very active and readily took to flight, even after being kept in a cool room.

In glasshouses, they were particularly addicted to settling upon foliage on which sunlight was falling, and the strong illumination and high temperature incited the females to make numerous feeding pits in the leaves by means of the strongly sclerotised spatulate ovipositor, which was extruded from the extremity of the abdomen.

After withdrawal of the ovipositor from each pit, which comprised a clear circular area 0·35 mm. in diameter immediately beneath the epidermis, the fly applied its mouth-parts to the puncture.

From time to time an egg was deposited in a similarly constructed pit, usually of more oblong shape. The flies were able to make their feeding and egg pits when settled upon the under surface of leaves, but even during spells of dull weather, the upper surface appeared to be preferred.

Previously it had been stated (Speyer 1944) that the pits occurred only upon the under surface of the cotyledons of seedlings and the upper surface of the rough leaves of older plants, but this has now proved to have been incorrect.

Owing to their shy disposition, the flies were difficult to capture, and in order to obtain living specimens within reasonable time limits, it was found best to drive them towards the side panes of the glasshouses by disturbing the foliage while walking from the centre path along the spaces between the rows of plants. The flies (and their parasites) settled upon the side-panes in their efforts to escape, and a glass tube was then placed over each fly, and a piece of thin dark paper slipped between the pane and the open end of the tube : on reversing closed end of the tube towards the light, the flies at once ran to that end, and a cotton-wool plug was inserted at leisure in the open end.

This reaction of the flies of both sexes to light proved of great value in handling them, as they could easily be transferred from one tube to another, or many of them could be assembled in a single tube. They could also be induced to come into contact for measurable periods of time with insecticides, small quantities of which had been placed upon the wool plug used to close the tube. When flies did escape in the laboratory, they always flew with little delay to the nearest window, upon the pane of which they were easily recaptured.

When the insects were liberated in glass-top boxes or in cages, a small tube containing them was held with the closed end towards the light, the plug or cork was removed from the open end, and the tube laid in the desired receptacle, which was then revolved until most light fell upon the open end, from which the insects escaped without delay.

It was found necessary to use dry tubes in which to keep the insects alive, for if they were enclosed in a very moist atmosphere, they soon lost all power of movement.

Both males and females fed readily upon syrup provided for them on small pieces of rubber sponge, which suggests that the latter sex is not entirely dependent for food upon the sap which it extracts from the feeding pits.

When plants in a tomato house, in which adult flies were numerous during May and June, were damped overhead, the flies which had been settling on the leaves disappeared, and did not return to them until the foliage had dried several hours later. As none of them could be found upon the lower surface of the leaves or upon the soil surface, it is probable that they flew to the upper structure of the glasshouse, whence, on warm days, some would doubtless have escaped through the open ventilators. Of 132 flies obtained from tomato houses in the Cheshunt district from April to June, 39 were males and 93 were females.

Although quite a number of males and females, some newly emerged from the puparia and others caught in glasshouses, were placed together in tubes, boxes, and cages, they were never observed to mate.

Some indication of the span of life was obtained from the following records taken in May and June :—

Of six females collected in a glasshouse and liberated in a large cage containing tomato pot-plants, some were still active on the sixth, but all had disappeared by the seventh day : many eggs were deposited in the foliage of the plants.

Of five males and four females, all newly emerged from the puparia, liberated in a cage containing a box of tomato seedlings, one male was seen alive four, and one female five days after : many eggs were laid in the cotyledons of these plants.

A newly emerged male lived for four days in a glass-top box containing a tomato leaflet, and females survived without food up to the fourth day in glass tubes.

A female which emerged from the puparia on 1st May was kept in a glass-top box containing a tomato leaflet, and was provided with syrup upon which to feed : on the fifth day a male was introduced into the box, and on the following morning both flies were liberated in a large cage containing six tomato pot-plants. The female, which later was discovered to have laid some 100 eggs, was seen to insert its ovipositor into the tissues of a leaflet on the sixth day, i.e., 11 days after its emergence from the puparium, but could not be found upon the following morning, and presumably had died.

Under the conditions cited, life of the adult flies did not, therefore, appear to be of longer duration than some four days for the male, and some 12 days for the female, but under more natural conditions it is possible that females, at any rate, live for much longer periods.

It had previously (Speyer 1944) been stated that the female rarely deposited more than one egg in the cotyledon of a single seedling, but the following record proves that this supposition is not always tenable. Some 200 tomato seedlings which had been germinated on 16th June were exposed to infestation over a period of five days in a glasshouse in which but few females could have been present. At the termination of this period, 26 seedlings had feeding or egg pits upon one or both cotyledons : none were observed on the rough leaves. Of the 36 cotyledons upon which pits had been made, 20 contained one egg each, five two eggs each, and in 11 no eggs had been deposited.

It has, however, been observed that the flies tend to distribute their eggs over comparatively

wide areas, but when confined in cages, or when comparatively few plants of a nature suitable to them are available, they deposited a number of eggs in a single cotyledon or leaflet.

2. Region of plant selected for oviposition and number of eggs deposited

A female fly which had emerged from the puparium five days previously and which had been fed on syrup during this period, was liberated with a male on the 6th May in a large cage containing six tomato plants, each bearing cotyledons and six rough leaves below the growing point : these were kept in a glasshouse in which high temperatures prevailed. Seven days later large numbers of pits had been made by the female fly, some on the cotyledons, but the great majority upon the lowest three rough leaves of each plant. By this time a number of eggs had hatched, and the larval mines were distributed over all the plants as follows :—in the cotyledons, one mine ; in the lowest rough leaves, 10 mines ; in the lowest but one, 12 mines, and in the third from the base, 2 mines. On the thirteenth day after liberation of the flies in the cage, 87 larvæ were extracted from mines in the leaflets and leaf stalks of five plants, two days later, 11 larvæ left their mines in the remaining plant in order to pupate, these having been trapped by means of an inverted paper cone tied round the base of the stem, and plugged with moist wool. The female fly, which had presumably remained alive in the cage for six days, had therefore deposited at least 98 eggs.

In a similar cage, containing one tomato plant upon which 10 rough leaves had developed below the growing point, six female flies caught in an infested glasshouse were liberated on 5th May : six days later, no living flies could be found in the cage. On the seventh day, 35 leaflets contained larval mines, with an average of two mines to each leaflet. On the fourteenth day after the flies had been introduced, mines were present in 43 leaflets out of a total of 50, up to the eighth leaf from the base of the plant : none had appeared in the four top rough leaves.

It was not found practicable to count the number of larvæ, but it was clear that the number of eggs laid had been very great.

It has been observed that the female flies, when free to do so, seldom deposit more than one or two eggs in the foliage of a seedling or young tomato plant. On account of the comparatively large number of eggs laid by each female, the emergence of a few flies from puparia contained in the soil beneath the staging may result later in larval mines making their appearance in a high proportion of the plants which have been raised in a propagating house.

Observations in glasshouses from March to June showed that larval mines occurred practically without exception in the lower leaves of tomato plants, and previous records have indicated that the flies only deposit eggs in leaves immediately round the growing point after the plants have attained a height of some six feet or more in late summer.

3. Period of incubation and duration of immature stages

Upon the plants in both cages referred to above, the eggs began to hatch upon the fourth or fifth day after the flies had been introduced into them : this period greatly exceeds that which had been computed from previous observations (Speyer 1944). At the beginning of June, when temperatures were higher, the period of incubation appeared to be from three to four days. During May, the larval life within the mine occupied a period of 9/11 days, and the flies began to emerge from the puparia after a further period of 17 days, giving a total of 32 days from deposition of the egg to emergence of the adult fly.

4. Duration of the pupal instar

(*a*) *Puparia kept under cool dry conditions.*

On 25th March, tomato leaflets containing mines of Liriomyza were collected from glasshouses at Goffs Oak, Herts. The mines had been vacated by the larvæ, which, in accordance with their usual habit, had evidently pupated in the soil : an abnormally large number of puparia, were, however, found adhering to the lower surface of leaflets.

Twenty-seven puparia were transferred to glass-top boxes and kept in dim light in a cool room.

Two of them, dissected respectively upon the 14th and 36th day after collection each contained a living pupa. No flies emerged up to the 41st day (on which an Hymenopterous parasite emerged from one of them). Between the 42nd and 60th day, two male and three female flies emerged. On 9th June (76 days after collection) the remaining 19 unemerged puparia were dissected : one contained a living fully-developed fly, and 18 each a fully developed dead fly (8 males and 10 females).

On 7th April, seven puparia were collected from the same locality and kept under similar conditions. No flies emerged from them up to the 60th day, on which they were found to contain two males and five females, all fully developed but dead.

On 14th April, six puparia, obtained from larvæ, which, during the previous night had vacated their mines in leaflets collected from the tomato plants in a glasshouse at the Cheshunt station, were kept under the conditions previously indicated. From one of them, a female fly emerged on the 15th day after formation of the puparium, and hymenopterous parasites from three others during the ensuing few days. On the 56th day after their formation, the remaining two puparia contained respectively a living pupa and a fully developed dead male fly.

When kept dry at comparatively low temperatures, the insects reached maturity, but only six out of 32 were able to effect emergence from the puparium.

(*b*) *Puparia kept under cool moist conditions*

On 15th April, full-grown larvæ which had vacated their mines during the previous night were placed upon moist soil contained in uncovered glass vessels : these were kept over wet sand in large partially closed jars in the laboratory. The larvæ buried themselves in the soil, and formed puparia within 24 hours.

There emerged between the 15th and 36th day, seven flies (four males and three females), between the 18th and 26th day seven hymenopterous parasites, and on the 27th day a dipterous parasite.

Upon the 33rd day after their formation, nine unemerged puparia were collected from the soil, one of which, on dissection, was found to contain a dead fully mature hymenopterous parasite.

The remaining eight puparia were transferred to glass-top boxes and kept in the laboratory until the 54th day, and then to a glasshouse in which very much higher temperatures prevailed. One of them, from which the anterior portion of the puparium case had been removed without injury to the insect within, was seen to contain a living pupa, which subsequently performed ecdysis to maturity.

Male flies emerged from the puparia in the glasshouse respectively on the third (57 days) and tenth day (64 days after formation), and a third fly (of which the sex was not determined) a few days later.

On the 15th day after their transference to the glasshouse (and 69 days after formation), the five unemerged puparia were dissected : three contained each a fully developed dead fly (a male, a female, and one of undeterminable sex), and the other two each a fully developed dead hymenopterous parasite.

Seven out of ten flies had effected their escape from puparia kept in moist soil at comparatively low temperatures—a far higher proportion than had been obtained when they were kept under dry conditions.

(*c*) *Puparia kept at higher temperatures*

On 18th May, a tomato pot-plant, the foliage of which contained many larval mines, was surrounded with an inverted paper cone, with its apex tied round the base of the stem and plugged with moist cotton wool : upon another plant a leaf containing several mines was enclosed in a cellophane bag.

The larvæ in the mines had been reared in a cage, kept in a warm glasshouse, from eggs deposited in the leaflets by a single fly 12 days previously.

Fifteen full-fed larvæ left their mines on 20th May, and had formed their puparia in the wool or bag by the following morning.

Nine puparia were kept without moisture in the glasshouse, in which the temperature rose to a high level during the day-time. On the 17th day after formation of the puparia, seven flies emerged : the two unemerged puparia were dissected two days later, and contained respectively a mature female and a teneral male fly.

The other six puparia were treated similarly, but kept upon cotton wool which was moistened daily. Again on the 17th day after formation of the puparia, five flies emerged, and the unemerged puparium contained a fully mature male fly.

The flies which actually emerged comprised in all seven males and four females.

At comparatively high temperatures, therefore, the period of pupation was much more regular, though it was not curtailed below the minimum (15 days) obtained under cool conditions. At the greater rate of development, the insects were not prevented from making their exit from the puparia through lack of moisture.

Information obtainable from these observations may be summarized as follows :—

(1) At comparatively low temperatures the rate of development within the puparium was very irregular. Flies emerged over periods ranging from 15 to 60 or more days from the time at which the puparia had been formed. Some puparia which still contained living pupæ after a period of some seven weeks were brought into a much warmer environment, and flies emerged from them in from three to about 12 days later.

When kept under cool dry conditions, the majority of the insects completed their metamorphosis within the puparium, but the mature flies were usually unable to break through the anterior end of the

puparium, and died within it. This occurred much less frequently in the case of puparia which were kept in moist soil.

Some explanation may therefore be forthcoming as to why it is that infestations develop when glasshouses are heated up for the propagation of plants in December and January, and a long period of time may elapse before larval mines again make their appearance in the leaves. Prediction as to the interval of time which may intervene between two successive generations appears to be practically impossible.

(2) Larvæ of Liriomyza parasited by Braconid Hymenoptera of the genera Pachysema and Opius formed their puparia in a normal manner. The adult parasites emerged from puparia kept at comparatively low temperatures over a period of 13 to 26 days : only in one instance was this prolonged to the 41st day. Some of the parasites which developed to maturity within the puparia were unable, like their host, to escape from them.

An emergence of parasites may therefore take place at a time when very few larvæ of the leaf-miner are present in a glasshouse, as a result of which these parasites may sometimes have little effect in reducing infestations, while at others they may bring a severe infestation under complete control, as they did at the Cheshunt Station after the beginning of June.

5. Incidence of infestation in relation to type of plant-growth

Observations of a general nature recorded during past years have indicated that tomato plants, whether growing in pots or in the ground, are much more susceptible to infestation when they produce a " soft " foliage. In April 1948 a severe infestation developed at the Cheshunt Station in a glass-house in which 18 different tomato varieties were raised : of these 12 produced soft, four medium, and two hard foliage, and larval mines were numerous on all the plots except the two with hard foliage. Flies from the glasshouse were periodically introduced into another containing hard plants, and throughout the season the number of larval mines which appeared in the leaflets was negligible. Towards the end of May some hard-grown pot-plants were placed upon staging in a portion of the latter house, and in their midst a single soft-grown plant of the variety Kondine was set : at the beginning of June larval mines were present in many leaflets of the soft plant, while only one of the many leaflets upon the hard plants contained a mine.

Experiments were arranged to determine if seedlings germinated in soil to which sulphate of potash had been added would develop cotyledons which the female flies might find difficulty in puncturing with their ovipositors, and conversely if addition of nitrogen to the soil would cause the seedlings to become more susceptible to infestation. A seed-box was divided into equal halves by a wooden partition, the one half being filled with standard propagating soil (steamed soil 4 parts, horse manure 1 part, with superphosphate at the rate of 1 part to 130 parts by weight of the mixture), and the other half with similar soil with which sulphate of potash had been mixed at the rate of 1 part to 100 parts by weight. In each half, 20 seeds of variety Potentate were sown on 25th May. The seeds germinated on 4th June. Three days later the seed-box was placed in a large cage in a glass-house, and four male and four female flies, all recently emerged from the puparia, were liberated in the cage.

On 11th June, when the box was removed from the cage, the flies had made pits upon 26 out of 33 cotyledons of the plants growing in standard soil, and on 19 out of 40 cotyledons of those in the soil to which sulphate of potash had been added : one larval mine had been started in a cotyledon of one of the latter plants. On 14th June the number of cotyledons containing larval mines was 15 in the standard and 17 in the partition which had received sulphate of potash. The growth of seedlings in the soil to which sulphate of potash had been added was retarded, and their rough leaves assumed a yellow colour which persisted for a period of some three weeks. On the 12th day after germination, their average height was $1\frac{1}{4}$ inches (as compared with $1\frac{1}{2}$ inches in the standard soil) and the average leaf span $1\frac{1}{2}$ inches (as compared with $2\frac{1}{2}$ inches in the standard soil). By the 21st June, when the larvæ, which had extended their mines into the rough leaves, were about to pupate, a considerable number of plants growing in the soil which had received sulphate of potash had collapsed.

In another experiment, one half of a seed-box was filled with soil with which sulphate of potash had been mixed at the rate of 1 part to 50 parts by weight of standard soil, and the other with soil containing 1 part dried blood to 100 parts by weight of standard soil. Four female flies collected from an infested glasshouse were liberated in the cage in which the seed-box had been placed, four days after germination of the seed. After two days, the flies had made pits on 16 out of 40 cotyledons in the partition which contained sulphate of potash, and on 22 out of 40 cotyledons in that which contained dried blood. The eggs began to hatch five days after liberation of the flies in the cage, and two days later larval mines had appeared in the cotyledons of 17 plants growing in the soil which

had received sulphate of potash : the plants had attained an average height of 1 inch and leaf span of ½ inch, and a number of them collapsed when the larvæ extended their mines into the rough leaves. Those growing in the soil mixed with dried blood had an average height of only ½ inch, and the rough leaves had hardly developed : eggs had been deposited in the cotyledons of almost every plant, and the seedlings collapsed soon after the larvæ began to feed.

The following conclusions were drawn from these experiments :—

Tomato seedlings raised from seed sown in soil to which sulphate of potash had been added were as susceptible to infestation as those grown in standard propagating soil : owing to unbalanced growth they were more liable to collapse after the larvæ, which hatched from eggs laid by the flies in the cotyledons, had extended their mines into the rough leaves. The flies deposited large numbers of eggs in the cotyledons of seedlings grown in soil to which dried blood had been added : the rough leaves of the plants failed to make growth, and when the larvæ began to feed, the seedlings collapsed. It must be pointed out that the amounts of potash and dried blood added to the soil were obviously excessive.

6. Experiments with DDT and BHC

The behaviour of the adult flies and of some Braconid parasites of Liriomyza was observed after they had come into contact with powder containing either DDT or BHC. In other experiments the soil surface was dusted with these powders to determine if the larvæ and teneral adults would be killed, the former when burying themselves to pupate, and the latter immediately after emergence from the puparia. DDT was used as a 5 per cent. powder, and in one experiment at a concentration of 0·04 per cent. as a suspension in water : for the experiments with BHC, a proprietary powder containing about 5 per cent. benzene hexachloride (and about 0·65 per cent. of its γ-isomer) was employed.

(*a*) *Effects of DDT upon the adult insects :—*

Three female flies which had settled for a few seconds upon a dusted leaflet were removed to a glass-top box containing a fresh tomato leaflet : none of the powder appeared to be adhering to their legs or bodies, and they were alive and active three days later.

A recently emerged male which had moved about on the surface of a dusted leaflet for about two minutes was removed to a fresh leaflet : the insect gradually lost control of its limbs, became completely paralysed in four fours, and subsequently died.

A recently emerged female was enclosed in a glass-top box upon the floor of which a lightly dusted leaflet had been placed : after three hours grains of powder were seen to be adhering to the legs and thorax, and the dusted leaflet was replaced with a fresh undusted one. Two hours later the insect was able to fly, but its movements did not appear to be normal, and it died within 16 hours.

Adult Braconid parasites (Opius and Pachysema) died much more rapidly after coming into contact with the powder : The movements of a female Opius which had walked for a few seconds over a lightly dusted surface, became unco-ordinated in 13 minutes, after one hour the insect could make use neither of its legs nor wings, and in three hours had become practically motionless.

Between 19th and 22nd May, six male and eight female flies (caught in an infested glasshouse) were liberated in a large cage in which two tomato pot-plants (variety Kondine) each of which had developed 11 rough leaves, had been enclosed after DDT powder had been applied to the upper surface of the foliage. None of the flies remained alive for more than 48 hours. Twelve days after the first batch of flies had been liberated, 13 larval mines had appeared in the leaflets of each plant.

In another cage containing two similar plants, the upper surface of which had been sprayed on the previous day with a 0·04 per cent. suspension of DDT, three male and four female flies were liberated on 20th May. On the next day at least one fly was alive, but on that following none were seen, and two males and two females were dead upon the floor of the cage. Eleven days after liberating the flies, 18 leaflets of one and 27 leaflets of the other plant contained larval mines.

As a control for these experiments, three male and four female flies were liberated on 19th May in a cage containing two similar plants to which no powder or spray had been applied. On the fourth day after their introduction, some living flies were present in the cage, and on the eleventh day 22 leaflets of one plant and 20 of the other contained larval mines.

The results obtained in these experiments appeared to indicate that the flies were not killed by a 5 per cent. DDT powder unless considerable quantities of it had become adherent to portions of their legs or bodies, and that when this occurred, a very appreciable period of time elapsed before they became inactivated. The flies were able to deposit a certain number of eggs in the leaflets of plants dusted with the powder. Doubtless the majority of these were laid in punctures upon the underside of the leaves, for it became obvious that the presence of powder upon the upper surface, apart from any deterrent action which might possibly have been due to the insecticide contained in it, made it

difficult for the insects to puncture the surface with their ovipositors. Such a barrier was evidently not created by the smooth deposit on the leaf surface after application of DDT in suspension, for here the number of eggs deposited by the flies was not less than that obtaining in the control.

A reduction, though hardly a significant one from an economic point of view, in the number of eggs laid by the flies followed the application of the 5 per cent. DDT powder.

(*b*) *Effects of BHC upon the adult insects :—*

A male fly which had emerged from the puparium upon the previous day, and which settled for five seconds upon a leaflet lightly dusted with BHC powder, was transferred to a glass tube. Sixteen minutes later its movements had become unco-ordinated and at 21 minutes the insect assumed an almost vertical position with the head held downwards : the wings were rapidly vibrated, causing the fly to gyrate in circles. This continued for four minutes, after which the wing vibrations became slower, and at 30 minutes all movement had ceased, except for spasmodic twitching of the legs. A female fly which had emerged from the puparium four days previously, and had been fed upon syrup during the intervening period, moved for 45 seconds over the surface of a leaflet dusted with the powder, and was then removed to a glass-top box containing an undusted leaflet. Fifteen minutes later its movements had become unco-ordinated and the insect was unable to take to flight. At 21 minutes the vertical position was assumed and vibration of the wings began, continued for 9½ minutes and then spasmodically and less rapidly for a further 3¼ minutes. The insect then made temporary recovery and actually fed upon syrup 30 minutes later, but after a further 15 minutes, the wing vibrations started again, and in an hour the fly was lying on its side : twitching of the mouth parts and extremity of the abdomen continued for another 45 minutes, after which the insect succumbed. Other flies of both sexes which were brought into contact with the powder in glass tubes behaved similarly, and became paralysed in from 45 to 90 minutes.

A female which was enclosed in a glass-top box containing a leaflet to which the powder had been applied six days previously was not quite dead after 18 hours though particles of the powder were adhering to the abdomen, and another female enclosed with a leaflet from a plant dusted seven days previously was alive and active after 25 hours. Braconid parasites of the genera Opius and Pachysema became paralysed some 15 minutes after they had come into contact with the powder, but they did not assume the erect attitude or vibrate their wings as was observed in the case of Liriomyza.

On 6th May the powder was applied lightly to a tomato plant which had developed 12 rough leaves below the growing point : the plant was placed in a large cage in a glasshouse in which high day temperatures prevailed. Three male and five female flies were liberated in the cage. After 50 minutes two females lay inert upon the floor of the cage, and on the following morning one male and one female were still alive, clinging to the roof : a few feeding or egg pits were discernable upon the extreme tips of some of the leaflets which had not been completely covered with the powder. On the 13th day after liberation of the flies in the cage, larval mines were present in 12 of the 33 leaflets up to the sixth leaf from the base of the plant. In another cage, containing a similar but untreated plant, into which six female flies had been introduced, larval mines were present in 43 of the 50 leaflets up to the eighth leaf from the base of the plant.

On 21st May the larvæ began to leave their mines in both plants in order to pupate.

Although a considerable reduction in the number of eggs laid in the leaflets was effected, it is thought probable that the BHC contained in the powder volatilized rapidly, and that female flies which happened to avoid immediate contact with the powder survived for a period of time sufficient to enable them to deposit a few eggs in the leaflets.

(*c*) *Application of powder to tomato seedlings :—*

On 21st June, boxes of tomato (variety Potentate) seedlings, which had germinated five days previously, were placed on staging in a small glasshouse and treated as follows :—

(i) One box of 32 seedlings : untreated.

(ii) One box of 37 seedlings : dusted with Kaolin—second application given two days later.

(iii) Two boxes of 42 and 44 seedlings respectively : dusted with 5 per cent. DDT powder—second application to one box given two days later.

(iv) Two boxes of 42 and 44 seedlings respectively : dusted with 5 per cent. BHC powder—second application to one box given two days later.

Three hours after application of the powder, three male and nine female female flies were liberated in the glasshouse.

During the course of the experiment, the soil was kept moist by lowering each box into water to the level of the soil surface, so that the powder on the foliage was not disturbed.

On 23rd June, feeding or egg pits made by the flies were present on the cotyledons of 30 plants in the untreated box (i) : on the seedlings of all the other boxes, tracks in the powder, made by the legs of the flies, were clearly visible, showing that they had settled upon the dusted foliage. After

this date no living flies were observed upon the plants. On 28th June the powders were removed from the foliage of the plants to which they had been applied, and a count was taken of the number of cotyledons upon which feeding pits had been made, and of the number which contained larval mines : no feeding pits or larval mines occurred in the rough leaves of any of the seedlings.

The results obtained are given in Table I.

TABLE I

Application of Powders to Tomato Seedlings

	No Treatment	Kaolin 2 Applications	DDT	DDT 2 Applications	BHC	BHC 2 Applications
No. of seedlings in box	32	37	44	42	44	42
No. of cotyledons with feeding pits ...	53	10	7	11	6	10
Ditto (per cent.)	83	14	8	13	7	12
No. of cotyledons with larval mines ...	35	11	8	9	4	7
Ditto (per cent.)	55	15	9	11	5	8
No. of plants with marks and mines ...	31	16	13	17	7	10
Ditto (per cent.)	97	43	29	40	16	24
No. of plants containing larvae	24	10	7	9	4	6
Ditto (per cent.)	75	27	16	21	9	14

As compared with the untreated control, there was a substantial reduction in the infestation upon all the seedlings which received application of any of the powders employed, even when an inert one such as kaolin was used, indicating that any deposit of powder upon the leaf surface may make it difficult for the females to puncture it with their ovipositor. It is possible that the majority of the feeding and egg pits upon the dusted plants had been made on the under surface of the cotyledons. No significant difference is shown between figures for the plants which received one, and those which received two applications of powder containing either DDT or BHC. Probably the flies had been killed off through settling upon the plants to which one or other of these insecticides had been applied before the second application was given.

(*d*) *Application of powders containing DDT and BHC to the soil surface :—*

An experiment was designed to determine, first, whether larvæ of Liriomyza at the time of pupation would be killed when burying themselves in soil the surface of which had been dusted with powder containing DDT or BHC and secondly if adult flies or parasites at the time of emergence from the puparia would be destroyed on finding their way to the dusted surface.

On 13th April, tomato leaves containing advanced larval mines were cut from plants and laid upon sheets of wet blotting paper, and during the two following days, larvæ which had vacated their mines were collected from the paper. Four glass jars were filled with moist soil ; the surface of one jar was liberally dusted with DDT powder and that of another with BHC powder. Ten larvæ were then dropped from a brush onto the soil in each jar, and all were seen to bury themselves within a few minutes. Three hours later, DDT powder was applied to the soil surface of one jar which had not previously been dusted.

Each jar was placed over moist sand covered with white paper in a separate large glass vessel, provided with a muslin cover and kept in dim light in the laboratory for a period of five weeks.

The following results were obtained :—

(1) Soil surface untreated.—Ten larvæ formed puparia : three male Liriomyza and four Hymenopterous parasites emerged between the 15th and 18th days.

(2) DDT powder applied before introduction of larvæ.—Six larvæ formed puparia : four Hymenopterous parasites (one of which died on the soil surface) emerged between the 19th and 23rd day. The two unemerged puparia, dissected after removal from the soil, contained each a dead adult Liriomyza.

(3) DDT powder applied after introduction of larvæ.—Nine larvæ formed puparia : one male and three female Liriomyza, only one of which died within 24 hours, emerged between the 15th and 35th day. A Dipterous parasite which emerged on the 25th day died within a few hours. Three Liriomyza emerged after the puparia had been removed from the jar, and one contained a dead adult fly.

(4) BHC powder applied before introduction of larvæ.—Six larvæ formed puparia : no flies or parasites emerged up to the 36th day, when one puparium contained a living pupa of Liriomyza ; the remaining puparia were dissected later, and contained respectively two

dead adult Liriomyza, two dead adult Hymenopterous parasites, and an apparently dead larva of the latter.

A high proportion of the larvæ, therefore, survived after having passed into the soil through a layer of powder containing either DDT or BHC, and they formed puparia in which they or the parasites which they contained completed their metamorphosis. After emergence from the puparia, a number of the adult flies and parasites survived after passing, in the reverse direction, through the layer of DDT powder.

No insects, having by chance, emerged from puparia in the soil dusted with BHC powder, during the course of the experiment, it was not possible to judge whether they would have survived, and a further trial will be carried out under more favourable conditions of temperature.

(*e*) *Summary of results obtained in experiments with DDT and BHC :—*

Adult flies which came into contact with a 5 per cent. DDT powder became paralysed after a considerable interval of time : a 5 per cent. BHC powder killed them much more radidly.

In experiments in which these powders were applied to the foliage of tomato seedlings and pot-plants, the number of eggs laid by the flies in the cotyledons and leaflets was reduced. Application of an inert powder, such as kaolin, to seedlings also effected a reduction, and it appeared, therefore that a deposit of any powder upon the leaf surface made it difficult for the flies to insert their eggs into the tissues. Application of DDT in the form of a wettable suspension, which left a smooth deposit on the leaf surface, did not bring about a reduction in the number of eggs laid in the leaflets.

Both powders rapidly killed adult Hymenopterous parasites which came into contact with them.

Considerable numbers of larvæ of the leaf-miner were able to bury themselves and form puparia in soil the surface of which had been dusted with either DDT or BHC powder : development within the puparia proceeded normally, and the insects (whether the leaf-miner or its parasites) reached maturity.

After emergence from them, some adult flies successfully made their escape after passing through a layer of DDT powder upon the soil surface.

References

Rep. Exp. Res. Sta. Cheshunt (1938), 24, 67-72.
Rep. Exp. Res. Sta. Cheshunt (1944), 30, 41-52.

2. RED SPIDER-MITE (Tetranychus telarius L.)

1. Azobenzene treatment upon a commercial nursery

On 12th April, mites in various stages of development upon tomato, peach, and nectarine, were collected from a block of glasshouses of 150,000 cubic feet capacity, in which an azobenzene canister, said to contain about 1 ounce of this compound, to every 4,000 cubic feet space had been ignited four days previously. The tomato plants were of the variety Potentate, and about 4 ft. in height ; the young peach and nectarine trees, of several different varieties, were planted along the ends of the block, which faced east to west.

At the time of collection, the majority of mites upon the foliage comprised eggs and resting nymphal stages. A few first instar nymphs, which might have hatched from eggs after the treatment, and some in the second instar showed feeble movement, but a number of third instar nymphs were very active : of the few adult males and females which were found, the majority were dead or moribund but a higher proportion of those upon peach and nectarine leaves were active.

From younger tomato leaves 50 eggs, nine first instar, three second instar, and five third instar nymphs, all in the resting phase were assembled on fresh leaflets and kept in the laboratory in dim light for a period of nine days, during which no eggs hatched and no nymphs or adults emerged from the nymphal skins.

An adult female which had assumed the red colour of the hibernating mite was transferred to a young tomato pot-plant upon which it remained on the upper surface of a leaflet for two days, and then evidently wandered into some crevice.

A female of the colour of the summer form, which did not appear to have been affected by the treatment, laid 11 eggs during the course of six days after its transference to a tomato plant : of these eggs, eight hatched from seven to nine days after their deposition : the three which failed to hatch subsequently were amongst those laid on the fourth day.

Four active females, from which the red colour of the hibernating form had almost disappeared, were collected from peach foliage and transferred to peach shoots with the cut ends of their stems in water. They laid many eggs, 50 of which were kept under observation. Five, which were left upon a shoot and exposed to sunlight, hatched on the seventh day after they had been deposited. The remainder were assembled upon tomato leaflets kept on moist filter-paper in dim light four to seven days after they had been laid : 39 hatched with an average incubation period of 8·6 days (range 6-12 days) and six failed to hatch.

From the material collected and kept under observation, it appeared that Azobenzene, projected into the atmosphere by the " smoke " method at the rate of about one ounce to 4,000 cubic feet space was effective in destroying at least the majority of eggs and resting nymphs present on the foliage at the time of treatment.

Adult female mites which had not been killed deposited viable eggs, which hatched after a normal period of incubation.

2. Viability of the eggs

Difficulties have been encountered in estimating the effects of acaricides upon eggs of the mite, owing to a high proportion of them failing to hatch amongst samples which have been employed as controls.

An attempt was therefore made to determine if conditions of temperature and light intensity might be factors which influence the development of the mite within the egg-shell.

In assembling the eggs within a conveniently small area upon the surface of a leaf, no difficulty has been experienced, with the aid of a binocular microscope and a fine needle, in transferring them from one leaf to another, and since all the eggs in comparatively large samples so manipulated have often hatched successfully, there is no reason to suppose that transference in this manner affects their viability.

Reference to the previous section shows that amongst eggs deposited upon tomato and peach foliage, nine out of 61 failed to hatch : of these, the five which were exposed to periods of sunlight all hatched, and it was amongst the remainder, which had been kept in dim light, that the non-viable eggs occurred.

On 26th April eggs were collected from older and younger leaves of Salvia grown in a glasshouse in which temperatures rose to a high level during day-time : they were assembled in convenient numbers upon the under surface of tomato leaflets, which were placed, with that surface upwards, upon moist filter-paper in boxes, partially closed so that an atmosphere near to saturation was maintained. Some samples were kept in total darkness, except during short periods of time necessary for daily examination, either in an incubator at 75° F. mean or at room temperature, and others in dim light at room temperature. Those eggs which had not hatched by the seventh day were kept for a further period of 10 days in full day-light, but only one of a sample of 67 (see Table II) hatched four days after removal from the incubator.

On 13th May eggs were collected from young tomato pot-plants : of two samples which were assembled on leaflets as previously indicated, one was kept in darkness and the other in full day-light. A batch of 14 eggs in situ upon a leaflet was also kept in full day-light.

The number of eggs which hatched, and the days upon which hatching took place, together with other details, are given in Table II.

TABLE II

Viability of Eggs under varying Conditions of Temperature and Light Intensity

Temperature	Light	Plant	Foliage	No. of Eggs in Sample	No. of Eggs hatched each day							Total No. of Eggs	
					1st	2nd	3rd	4th	5th	6th	7th	Hatched	Not Hatched
75° F.	None	Salvia	older	30	5	1	–	–	–	–	–	6	24
,,	,,	,,	younger	67	3	14	27	6	7	3	2	62	5*
room	none	,,	older	30	–	2	–	–	–	–	–	2	28
,,	,,	,,	mixed	30	–	1	3	1	3	5	5	18	12
,,	dim	,,	mixed	60	6	7	4	–	–	–	1	18	42
,,	none	Tomato	young	20	–	–	3	–	2	13	2	20	0
,,	full	,,	,,	50	–	1	19	–	26	–	–	46	4
,,	,,	,,	,,	14	–	–	1	–	13	–	–	14	0

* One egg hatched on fourth day after removal from incubator.

Aeolothrips fasciatus L × 30.
Male above, female below.

Assay of extracts a & b made from a soil-straw compost of the same composition.

a.—Soil inoculated and extract made afterwards. Note stimulation.

b.—Extract made first and inoculated afterwards. Note inhibition.

A very high proportion of eggs collected from older leaves of Salvia failed to hatch. A number of the unhatched eggs contained nymphs which had developed their eye-spots and appendages, and, for some reason unknown, had been unable to break through the egg-shell. It became evident that the nymphs had dried up some time before the samples had been collected, and on this account the eggs had retained their contour, and did not differ in appearance from recently laid eggs : these unhatched eggs appear to have accumulated upon the older leaves, and therefore represented a high proportion of the total collected.

3. STUDIES UPON THYSANOPTERA

An examination of British species in the genus Æolothrips has been carried out. In structure, the representatives of the genus are amongst the most primitive forms of existing Thysanoptera.

Several species occur commonly in flowers of low-growing plants and upon grasses, while others, less frequently met with, inhabit trees and shrubs. They are active insects some 2 mm. in length, with shaded areas upon their comparatively broad wings, the longitudinal veins of which are united typically by four cross-veins. According to Doecksen (1941, p. 27) they feed upon pollen, but their larvæ are predatory upon mites and small insects, including, in particular, members of their own Order.

The genus Æolothrips was raised by Haliday (1836), to include the species *fasciatus* L. (1758), *albicinctus* Hal. and *vittatus* Hal. and later (1852) he added *melaleucus* Hal. Uzel (1895) described *versicolor*, and in more recent years Bagnall has named a number of species, of which, amongst those found in Britain, only *ericae* (1920) and *tenuicornis* (1926) are here considered to be valid.

Æ. fasciatus L. the genotype (figs. 1 and 2), has been referred to in literature as common and widely distributed over Europe and N. America, but there can be no doubt that two distinct species have been confused under this name. Both species are common and often occur together in the flowers of many wild and cultivated plants, and also upon grasses. One of them has been named *tenuicornis* Bagnall and there is a third allied but distinct species, *ericae* Bagn. found principally upon heather and broom.

It is not known to which species Linnaeus gave the name *fasciatus*, but it was in all probability to one of these three : it would therefore appear justifiable to retain the names *ericae* and *tenuicornis* and regard the remaining species as the true *fasciatus* L. *Æ. albicinctus* Hal. differs in a number of structural characteristics from other species of the genus : the males are always and the females usually brachypterous but never, apparently, apterous. The species is an inhabitant of grasses.

Comparatively few specimens of *Æ. melaleucus* Hal. and *Æ. versicolor* Uz., and only their females, have been available for study. Males have apparently not been described, and in their absence there is often difficulty in determining whether females of closely allied forms belong to different, or are only varieties of a single species. It has been considered best, for the present, to regard these two species as distinct, though they have a closely similar habitat on broad-leaved trees and upon shrubs : they are separable, apparently, only upon differences in the colour of the antennæ and legs. The female of *Æ. similis* Priesner (1919) resembles that of *versicolor* so closely that it is regarded as a variety of that species.

Æ. vittatus Hal. is the only species which inhabits coniferous trees : the male is unknown, but the female is readily separable from other species of the genus on characteristics of the fore-wing. Characteristics for the separation of the species are given at the conclusion of this essay.

(a) Variation within the species

Some attempt has been made to record the measure of variation which may occur within the species in characteristics which have, at least to some extent, been employed in the past for separation of certain species in this genus. For this purpose the species *fasciatus* L. and *tenuicornis* Bagn., of which large numbers of mounted specimens were available, were selected.

Males of the two species are readily separable upon structural characteristics : Doecksen (1941 pp. 54-55) states that the genitalia of *Æ. clavicornis* Bagn., which is now regarded as conspecific with *tenuicornis*, differ structurally from those of *fasciatus*. The females, however, closely resemble one another, and the only constant characteristic as yet observed by which they may be separated relates to the tip of the fore-wing, the costal vein of which in *fasciatus* is clear and in *tenuicornis* shaded in this region. The difference is shown in both sexes of the two species.

In his collection, Dr. C. B. Williams had segregated a long series of specimens into two categories upon this characteristic, and in each there were a number of males and females which had been taken

in the act of mating, or in close association with one another. It was observed that males of the one category had in no case paired with females of the other.

Further evidence to show that males of the one species are not likely to pair with females of the other was afforded from specimens collected in flowers of Matricaria (May-weed) at Cheshunt in July. Here males and females with " clear " but only females with " shaded " wing-tips occurred : a number of males, referable to *fasciatus*, were taken in the act of pairing with females of the former, but none with females, referable to *tenuicornis*, of the latter category.

Upon this evidence it was concluded that *fasciatus* and *tenuicornis* were separate species.

(i) *Dimensions of antennæ and wings*

Twenty-four males of each species, 10 females of *fasciatus* and eight females of *tenuicornis* were selected.

In Table III measurements are recorded of the length of the tibia of the hing leg, of the antenna, its third and fourth joints and of the sensorium upon the latter, and of the breadth of the fore-wing, taken at about one-third of its length from the tip : ratios of certain of the measurements to one another are added, with that pertaining to the proportions of the third antennal joint.

The average is given for each set of measurements with the range of variation indicated by the sign ±.

TABLE III

Variation in Aeolothrips—Measurements in μ (=0·001 mm.)

	fasciatus L.		*tenuicornis* Bagn.	
	Male	Female	Male	Female
Hind tibia	299±30	334±22	296±36	334±22
Antenna				
Total length	418±73	448±63	398±45	467±59
Third joint	91±17	106±17	92±19	108± 7
Fourth joint	90±12	87±19	80±18	91±10
Sensorium	41± 5	47± 5	28± 6	32± 5
Fore-wing (breadth) ...	144±14	165±30	159±15	179±22

The following ratios were recorded:—

	Male	*Female*
fasciatus L.		
Hind tibia/third+fourth antennal joints (length)	1·65±0·13	1·73±0·17
Fourth antennal joint/sensorium (length)	2·20±0·35	1·90±0·25
Fore-wing (breadth)/hind tibia (length)	0·48±0·06	0·49±0·04
Third antennal joint: length/diameter	3·80±0·80	4·30±0·80
tenuicornis Bagn.		
Hind tibia/third+fourth antennal joints (length)	1·71±0·32	1·69±0·06
Fourth antennal joint/sensorium (length)	2·80±0·50	2·80±0·40
Fore-wing (breadth)/hind tibia (length)	0·53±0·04	0·55±0·02
Third antennal joint: length/diameter	3·80±1·15	4·10±0·70

The figures indicate that there is wide variation in the length of the antennæ and several of their joints, and in the breadth of the fore-wing of each species, as a result of which considerable overlapping occurs between them. They would appear to show that the sensorium upon the fourth antennal joint occupies a larger area in *fasciatus* than in *tenuicornis*, but the difference is not considered to be significant, and when larger numbers of specimens were examined for this character there was found to be overlapping, the ratio range for males being 1·9—2·6 in *fasciatus*, 2·3—3·3 in *tenuicornis*, and for females 1·6—2·2 in *fasciatus*, 2·1—4·0 in *tenuicornis*.

No significant differences could be found between females of the species *fasciatus*, *ericæ*, and *tenuicornis* in the proportions of the antennal joints. In all three, the third joint was 3·9—4·6 times as long as the diameter and 1·2 times as long as the fourth joint : the fourth joint 3·3—4·0 times as long as the diameter and 1·1 -1·3 times as long as the fifth joint : the fifth joint 2·8—3·6 times as long as the diameter and 1·2 times as long as the sixth to ninth joints measured as a unit.

It was concluded that measurements of this description are of little value for the separation of the species, at least in this genus.

(ii) *Colouration*

In a number of Æolothrips species an orange or red pigment occurs in the bodies of the females. Of 39 specimens of *fasciatus*, 33 contained the pigment, three traces of it, and in three it was wanting. Of 34 specimens of *tenuicornis*, 16 contained the pigment, and in the remaining 18 it was wanting. It is suggested that the pigment may be somewhat similar to that which occurs in the bodies of many Aphides, and its presence, intensity, or absence may therefore be of an entirely fortuitous nature.

No differences could be detected in the colour of the body, the several antennal joints, and the legs, between *fasciatus* and *tenuicornis*. In a long series of *ericæ* in the British Museum collection, the second antennal joint and the 10th and 11th abdominal segments were always pale and unicolorous, apparently the only constant characteristics which served to separate the female of this species from that of *fasciatus*.

In a few males, amongst many, of *tenuicornis*, the colour of this joint was similar, but in the females and in both sexes of *fasciatus* it was always dark or partially dark, even in teneral specimens.

(b) Chætotaxy

At any rate in all British species the setæ upon the dorsal surface of the head, prothorax, and first eight abdominal segments are very short, and their arrangement appears to be very uniform throughout the genus. Only in females of *Æ. albicinctus* Hal. are those upon the portions of the abdomen longer than in other species.

It is thought that there may be slight differences in the disposition of setæ upon one or other of the more posterior abdominal sternites, which might serve as additional characteristics for separation of the females of some species, but it has not been possible to obtain sufficient information owing to the difficulty of examining the ventral surface of specimens which have been mounted dorsal surface upwards upon comparatively thick microscope slides.

It has been noted that considerable variation may occur in the length of setæ upon the ninth abdominal tergite of males and the eighth abdominal tergite of females of *fasciatus* L.

(c) Synonymy

With the foregoing data, examination of type specimens in the British Museum, and reference to published descriptions of them, it became apparent that some species described by more recent authors under different names were referable to one or other of the three species *fasciatus* L, *ericæ* Bagn. or *tenuicornis* Bagn. From an examination of the type specimen, it has been concluded that *Æ. propinquus* Bagn. (1924) is not similar to the species described under the name *astutus* Priesner (1926), specimens of which from Denmark were available for comparison. The structure of the foretarsus which, in *astutus*, is unlike that of all other known European species, does not appear to differ materially from that of *fasciatus* L, and in other characteristics "*propinquus*" resembles the latter species. *Æ. astutus* has probably as yet not been recorded in Britain.

The following synonymy for the species referred to is suggested :—

fasciatus L (1758)—*propinquus* Bagnall (1924) (nec *astutus* Priesner 1926) : *intermedius* Bagnall (1934).
tenuicornis Bagnall (1926)—*anthyllidis* Bagnall (1932) : *clavicornis* Bagnall (1934).

(d) The Larvæ

Except for a few specimens presumably referable to *fasciatus* L., no larvæ were represented in the British Museum collection. In Dr. Williams' collection some specimens of *ericæ* Bagn. and *vittatus* Hal. were available.

A considerable number of larvæ of *fasciatus*, and probably some of *tenuicornis* have been collected and examined, but no characteristics have as yet been observed whereby they can be separated, either from one another or from those of *ericæ*.

In addition to those of *vittatus*, two second instar larvæ probably of *albicinctus* and one of *melaleucus* have been obtained. The characteristics in which these appear to differ from *fasciatus* (see Speyer and Parr 1941, pp. 585-6) are as follows :—

albicinctus Hal. : Sixth antennal joint longer ; only one pair of grey spots on dorsal surface of prothorax.

melaleucus Hal. : No grey spots on dorsal surface of prothorax ; majority of setæ upon the dorsal surface, particularly of the head, notably longer.

vittatus Hal. : One, and sometimes an additional smaller pair of grey spots on dorsal surface of prothorax.

It would appear probable that the larvæ of different species in the more primitive, may resemble one another more closely than those in the more specialized genera of Thysanoptera.

(e) Characteristics of the British species

A chart illustrating characteristics of the British species of Æolothrips is appended, with a key for additional ones applicable to those males which have been available for study. Doeksen (1941, p. 34 and fig. 92) draws attention to a blunt projection surmounted by a chitinous comb on the inside of the mesothoracic coxa in males of *Æ. fasciatus* L. This structure has been found to be well developed in such males both of that species and of *tenuicornis* Bagn. as it has been possible to examine properly in ventral aspect. The shape of the projection appears to be subject to much variation, sometimes being more pointed upon the coxa of one side than upon that of the other in one and the same specimen. The structure is present also in males of *Æ. ericæ* Bagn., but rudimentary in those of *Æ. albicinctus* Hal.

TABLE IV

GENUS AEOLOTHRIPS. CHARACTERISTICS OF BRITISH SPECIES

	fasciatus L.		*ericae* Bagn.		*tenuicornis* Bagn.		*albicinctus* Hal.		*melaleucus* Hal.	*versicolor* Uz.	*vittatus* Hal.
Fore-Wing	♂	♀	♂	♀	♂	♀	♂	♀	♀	♀	♀
Apex broadly rounded	×	×	×	×	×	×	–	×			
„ more pointed									×	×	×
With two dark transverse bands:											
Completely separate	×	×	×	×	×	×	–	×			
Confluent posteriorly									×	×	
With one long transverse band:											
Covering surface										×	
Confined distally to posterior moiety											×
Costa round apex, clear	×	×	×	×					×	×	×
„ „ „ shaded					×	×	–	×			
Antenna											
Second joint at least partially dark	×	×			×	×	×	×	×	×	×
„ „ pale, unicolorous			×	×	×						
Fourth joint at least partially dark	×	×	×	×	×	×	×	×	×		
„ „ pale, unicolorous										×	×
Hind tibiae and tarsi											
Unicolorous, dark	×	×	×	×	×	×	×	×	×		×
Tibia distally and tarsus light										×	
FEMALES (including brachypterous forms)											
Abdomen											
First tergite: integument lightly reticulate		×		×		×			×	×	×
„ „ „ densely striate								×			
Second and third segments: at least partially sclerotised		×		×		×			×	×	×
Second and third segments: unsclerotised											
Second to seventh tergites: median setae 15–20μ long		×		×		×			×	×	×
Second to seventh tergites: median setae 30–40μ long								×			
Tenth and eleventh segments: sclerotised		×		×		×			×	×	×
„ „ „ „ unsclerotised				×				×			

MALES

1. (6) Macropterous: Fourth and fifth abd. tergites each with a pair of raised sclerotised processes; ninth abd. segment laterally with clasping hooks.
2. (3) Processes on sixth tergite, if present, very inconspicuous (those on fourth tergite cubical). Marginal seta anterior to base of clasper filiform, straight or slightly curved. ... ... *fasciatus* L.
3. (2) Processes on sixth tergite conspicuous. Marginal seta at base of clasper stout, strongly curved.
4. (5) Processes on fourth tergite much broader than long, weakly sclerotised. ... ... *ericae* Bagn.
5. (4) Processes on fourth tergite cubical, their apices strongly sclerotised. ... ... *tenuicornis* Bagn.
6. (1) Brachypterous: Fourth and fifth tergites devoid of raised processes. Ninth abd. segment devoid of clasping hooks. ... ... *albicinctus* Hal.

NOTE.—Males of other British species appear to be unknown. Brackets in the chart denote that either of the two characteristics may occur in the one species.

Acknowledgments

Acknowledgments are due to Mr. F. Laing of the British Museum (Natural History) and to Dr. C. B. Williams of the Rothamsted Experimental Station for the great assistance which they have given in this investigation.

References referred to in the text

Bagnall, R. S. Ent. Mon. Mag. 56, p. 60, 1920.
—— *ibid* 60, p. 269, 1924.
—— *ibid* 62, p. 280, 1926.
—— *ibid* 68, p. 161, 1932.
—— *ibid* 70, pp. 122-3, 1934.
Doeksen, J. Bijd. vrg. Morph. Thys. Wageningen, 1941.
Haliday, A. H. Ent. Mag. 3, p. 451, 1836.
—— Homopt. Ins. Brit. Mus. p. 1117, 1852.
Priesner, H. Zeit Œst. Ent. Ver. 4, p. 80, 1919.
—— Thys. Eur., p. 109, 1926.
Speyer, E. R. and Parr, W. J. Trans. R. Ent. Soc. 91, pp. 585-6, 1941.
Uzel. Mon. Thys. p. 69, 1895.

4. INSECTICIDE INVESTIGATIONS

W. H. READ

The number of new insecticidal materials has increased considerably as a result of investigations in many countries. The most important discoveries, so far as the control of glasshouse pests are concerned, are those of Schrader and his co-workers, described by Martin and Shaw[1], since several of the organic phosphorus compounds are highly toxic to the glasshouse red spider mite (*Tetranychus telarius* L.). Although azobenzene, dispersed by spraying solutions of it in a volatile solvent into the air of glasshouses, or by volatilization from pyrotechnic mixtures, has largely replaced the use of petroleum emulsions, there is need for a more satisfactory medium for the control of red spider. The insufficient kill of adult mites obtainable with azobenzene under practical conditions necessitates frequent applications to prevent an increase of mite population.

The acaricidal (mite killing) values of several organic phosphorus compounds have been investigated both in the laboratory and in glasshouse trials. The ovicidal values of a number of substances structurally similar to azobenzene have been determined in laboratory tests using eggs of the glasshouse red spider. No satisfactory laboratory method has been devised for critical determination of the potency of substances as contact insecticides using adult mites and the great delay in obtaining delivery of apparatus required for the examination of smokes and mists has made it impossible to carry out the laboratory examination of insecticides applied by these means.

Organic Phosphorus Compounds

The 1947 report contained references to the substance hexaethyl tetraphosphate (HETP). Additional tests have been made with this and also with commercial tetraethyl pyrophosphate (TEPP), which may be regarded as a more potent form of HETP. The other substance tested was p. nitrophenyl diethylthiophosphate (E. 605 or " Parathion ") which differs from the first two substances in that it is sufficiently stable to form residual films on treated surfaces and is also appreciably volatile.

Hexaethyl tetraphosphate (HETP) and Tetraethyl pyrophosphate (TEPP)

These two substances may well be dealt with together since the main insecticidally active material in both of them is tetraethyl pyrophosphate. The commercial product HETP contains about 20 per cent., and commercial TEPP about 40 per cent. of pure tetraethyl pyrophosphate. Determination of the tetraethyl pyrophosphate content of the commercial products used in the most recent work were made by the method of Hall and Jacobsen 1948[2].

The ovicidal activities of HETP and TEPP towards the eggs of the glasshouse red spider (*Tetranychus telarius* L.) were determined by a dipping technique and the median lethal concentrations as estimated from provisional regression lines and given in Table 1, show that these substances have no appreciable ovicidal value and that the toxicity to the eggs is closely related to the tetraethyl pyrophosphate content. Both are highly effective against active stages of this mite, however, and the concentrations giving 100 per cent. kill of adult female mites are included in Table 1. No estimates

of median lethal dosages to adult mites have been made since no technique suitable for the accurate determination of the acaricidal value of substances using adult glasshouse red spider mites was available.

In the course of glasshouse trials with HETP it was observed that tomatoes and to a lesser degree chrysanthemums were susceptible to damage from aqueous HETP sprays. The nature of the phytotoxic principle of HETP was investigated therefore, in the course of which the tetraethyl pyrophosphate fraction was isolated from commercial samples of HETP and TEPP by the method of Hall and Jacobsen[2] and shown to be responsible for the injury to plants. The products resulting from the hydrolysis of tetraethyl pyrophosphate, and the portions of the commercial products remaining after the tetraethyl pyrophosphate had been extracted with chloroform were non-injurious. The extracted tetraethyl pyrophosphate and residue after its extraction were applied to plants without delay after the commencement of the extraction, to avoid complications due to hydrolysis. " Lissapol N " at 0·02 per cent. was used as the wetting agent in these trials.

The results of these tests are summarized briefly as follows. Young tomato plants (varieties Potentate and Ailsa Craig 10-12 leaves) were injured by the application of sprays containing 0·025 per cent. TEPP or 0·05 per cent. HETP when the plants were kept at a high temperature (80° F.) under conditions of low humidity (52 per cent. r.h.) for a period of six hours after treatment. The injury at these concentrations was confined to an initial downwards curling of the edges of the leaves, and ultimate reduction in leaf expansion, i.e., " hardening."

At low temperature (50° F.) or at high temperatures under humid conditions, no injury resulted from the application of TEPP or HETP at the above respective concentrations, which are equivalent to 0·01 per cent. pure tetraethyl pyrophosphate.

At higher concentrations (0·05 per cent. TEPP and 0·1 per cent. HETP) young tomatoes were severely scorched, particularly when retained in a dry atmosphere after treatment.

The resistance of plants increases with their age but on a number of occasions planted out tomatoes, 3 ft. high, were damaged by single applications of sprays containing 0·1 per cent. HETP or 0·05 per cent. TEPP.

There is some evidence that certain varieties of tomato may be more susceptible than others.

When the readily hydrolysed products in HETP have been hydrolysed by allowing a 0·5 per cent. solution in distilled water to stand for 48 hours, the solution is not phytotoxic to tomatoes, and the residue remaining after the extraction of the tetraethyl pyrophosphate from TEPP by the method of Hall and Jacobsen[1] is not phytotoxic to tomatoes at a dilution which contains the non-tetraethyl pyrophosphate fraction in amounts equivalent to those present in a 0·25 per cent. solution of commercial TEPP.

These results show that great caution is necessary in applying HETP and TEPP sprays to tomatoes, especially when the plants are young, and they should not be applied to seedlings or soft young pot plants.

Chrysanthemums were found more tolerant to HETP and TEPP than tomatoes and no injury to any of the varieties examined occurred with TEPP at dilutions greater than 0·05 per cent. There have been several reports of injury to chrysanthemums from HETP at dilutions as low as 0·06 per cent. and since some varieties of chrysanthemums are probably much more susceptible than others caution is necessary when using HETP at 0·05 per cent. or TEPP at 0·025 per cent., particularly on young plants under glass.

TABLE I

Toxicity of Organic Phosphorus Compounds to the Glasshouse Red Spider. (*Tetranychus telarius* L.)

Substance	Ovicidal Action. Medium lethal concentration	Acaricidal Value. Lowest concentration giving 100% kill of adult Females
	%	%
HETP*	0·35	0·018
TEPP†	0·22	0·01
E.605 (Parathion) ...	0·034	0·0028

* Tetraethyl pyrophosphate content: 20·3 per cent.

† „ „ „ 36·9 „

p Nitrophenyl diethylthiophosphate (E 605 or Parathion)

This organic phosphorus compound is more volatile than HETP or TEPP and as a result is considered more physically suitable for the control of pests in glasshouses by the processes commonly termed the " aerosol " method and the " smoke " method. Undesirable features which may be connected with its use are discussed elsewhere.

Samples of the commercial ester, were examined for ovicidal action by the dipping technique using the eggs of the glasshouse red spider, and the greatest dilution at which complete kill of adult female mites was obtained was also determined. The results obtained are included in Table 1 and show that E 605 has considerable true ovicidal action. Although a dolution of 0·25 per cent. was required to give complete inhibition of egg hatching the practical results obtained were superior owing to the fact that many of the larvæ die very shortly after hatching, possibly due to the residual film which may be present under the conditions of this test.

Preliminary work on the persistence and practical insecticidal value of residual films of E 605 has been commenced.

The ovicidal action of substances structurally similar to azobenzene

The toxicity of a number of compounds having structural similarity to azobenzene, to the eggs of the glasshouse red spider (*Tetranychus telarius* L.) has been investigated.

The method employed was as follows. Discs about 1 cm. in diameter and having between 20 and 50 eggs on them were cut from leaves. Pansy (*Viola tricolor*) leaves were employed since they were substantially free from leaf hairs which tend to make counting of the eggs more difficult and entrap air bubbles when the leaves are dipped. Young leaves recently infested with mites were selected to avoid as far as possible any accumulation of non-viable eggs. The discs were held at a point on their periphery with a pair of fine pointed forceps, dipped in the dilution of the substance under test for 15 seconds with gentle movement and then held for 10 seconds with the lower edge touching the beaker holding the fluid in order to drain. They were then placed eggs uppermost on sheets of filter paper to dry. When dry and slightly wilted (not curled through drying too much) the discs were carefully stuck to glass microscope slides with gum and all stages of the mite apart from eggs removed.

The eggs were then counted and the discs surrounded with a very thin circle (smear) of soft vaseline. After incubating for at least 18 days at a temperature of approximately 20° C., the larvæ trapped in the circle of vaseline were counted. The discs were also examined for larvæ which might have emerged but failed to entrap themselves. If necessary the unhatched eggs may also be counted by this method.

Methods for the laboratory determination of the toxicities of substances to adult mites have been investigated but no satisfactory method has been found for the precise determination of the relative toxicities of substances to adult mites.

The laboratory assessment of the relative toxicities of substances to both the eggs and adult females of the glasshouse red spider are rendered difficult by the very high degree of heterogeneity of the test material. A feature of the tests was the frequent high mortality of the untreated eggs in spite of the careful selection of material from young leaves onto which the mites had recently moved and on which non-viable eggs were unlikely to have accumulated.

Attempts were made to obtain test material consisting of eggs differing not more than two days in age by transferring mites, including cocoons of mites, to previously uninfected plants, but no practical method has been devised so far for obtaining the large number of eggs required.

Of the substances tested as ovicides against the eggs of the glasshouse red spider only azoxybenzene and hydrazobenzene had toxicities of the same order as azobenzene. Diphenyl sulphone, shown by Eaton and Davies[8] to be as toxic as azobenzene to the fruit tree red spider (*Metatetranychus ulmi* Koch), was considerably less toxic than azobenzene to eggs of the glasshouse red spider and was of about the same order as dibenzylamine and nitroso-diphenylamine. Benzyl benzoate, also stated by Eaton to be as toxic as azobenzene, was much less toxic to the glasshouse red spider under the conditions of these tests. In this connection it is of interest to note that benzyl benzoate was found of no practical value when applied as an " aerosol " in glasshouse trials.

Naphthalene, once widely employed as a fumigant for the control of red spider on cucumbers and carnations, was found to have very low toxicity under the conditions of these tests.

Statistical examination of the results has not been made so far but if statistical interpretation is possible the full results will be published elsewhere.

Investigations on the crop in glasshouses

(1) Organic phosphorus compounds as ærosols

It is advantageous to apply insecticides in glasshouses by dispersing them in the form of mists

(" aerosols ") or smokes instead of spraying them directly on to plants in aqueous dilutions and experiments have been made in which HETP, TEPP, E 605 (" Parathion ") and mixtures of azobenzene with TEPP or with E 605 were dispersed by spraying acetone solutions of them with a compressed air operated paint spray gun. In view of the inconsistent results obtained in these tests much more work in connection with factors such as the effect of temperature, humidity and concentration of the solution of the compound is necessary.

When experiments were conducted in a chamber of 750 cubic feet complete control of aphids (*Myzus persicæ* Sulz and *Myzus ornatus*) and of active stages of the glasshouse red spider mite on detached leaves was obtained with 0·65 gram of HETP per 1,000 cubic feet. Larger scale trials in a carnation house of 22,400 cubic feet and in cucumber houses 18,000 cubic feet failed to give satisfactory control of the aphids *Myzus persicæ* and *Doralis symphiti* Schrank, respectively with a dosage of 1·5 gram HETP per 1,000 cubic feet.

Mixtures of azobenzene with HETP, the addition of the latter being made with the object of improving the control of active stages of the mite, have likewise yielded inconsistent results.

Para-nitrophenyl diethyl phosphate (E 605 or " Parathion ") has given complete control of active stages of the glasshouse red spider mite at 0·3 gram per 1,000 cubic feet in preliminary trials and the treatment of houses with a mixture of 0·3 gram E 605 and 4 gram azobenzene per 1,000 cubic feet has given results superior to those obtained from 6 grams azobenzene per 1,000 cubic feet.

Observations made in tests with E 605 against red spider mites have shown that adult white flies (*Trialeurodes vaporariorum* Westw.), and thrips (*Thrips tabaci* Lind. and *Heliothrips hæmorrhoidalis* Bouche) are killed by 1 gram E 605 per 1,000 cubic feet, but no experiments have been made to determine if lower dosages are effective.

Owing to the highly poisonous nature of these organic phosphorus compounds it is necessary to wear a respirator when applying them as aerosols. HETP and TEPP may be regarded as non-volatile and as they are readily hydrolysed to non-poisonous compounds there is no danger to persons working in treated houses which have been aired for a short time after the period of treatment, and treated vegetables and fruits can be consumed 48 hours after treatment.

Until more is known about the persistence of residues on treated plants, E 605 must not be used on food crops and treated houses must be well aired before people work in them.

(2) The control of the green peach aphid (Myzus persicæ Subz.) on carnations with HETP

Sprays containing Hexaethyl tetraphosphate (HETP) were compared with sprays containing nicotine for the control of aphids on carnations. Carnation beds at the Research Station were sprayed with HETP (20·0 per cent. tetraethyl pyrophosphate) at concentrations of 0·067 per cent. and 0·5 per cent. and nicotine at 0·1 per cent. and 0·067 per cent. Lissapol (0·025 per cent. was incorporated in all the spray fluids as a wetting agent. The results of these trials were judged visually by observing, 18 days after treatment, the degree of infestation of plants selected as being equally severely infested before treatment.

The trials showed that nicotine at 0·067 per cent. failed to give satisfactory control and that HETP at 0·05 per cent. was equal to nicotine at 0·1 per cent. Additional trials have been made on commercial nurseries and the value of HETP sprays confirmed.

(3) The effect of TEPP and E 605 (Parathion) on woodlice (Armadillidium speyeri Jackson) in soil

Preliminary experiments were made to determine the effect of the organic phosphorus compounds on woodlice with a view to larger trials in cucumber beds should they show merit. In order to make the test stringent the woodlice were placed on the top of an inch layer of coarse sand in 4-in. pots and immediately covered with three inches of a uniform compost taken from an old cucumber bed. This compost was very rich in organic matter and had a pH of 7·2. The pots were then watered with 100 ml. of the insecticidal fluid and kept at a temperature of 65°. Twenty woodlice were employed in each test and the tests made in duplicate. The numbers of living and dead or moribund woodlice were counted after 24 hours. Those living were replaced in the compost and again examined after 5 days. DDT, Benzene hexachloride (BHC) and nicotine were also included in these trials.

The results (Table 2) show that under the conditions of the test it was necessary to use TEPP at a dilution of between 0·25 per cent. and 0·125 per cent. to obtain 100 per cent. kill of woodlice in 24 hours and E 605 at between 0·1 per cent. and 0·05 per cent. Complete kill was obtained in five days with 0·025 per cent. E 605.

E 605 shows considerable merit and trials will be made against woodlice in cucumber beds. It must be emphasized, however, that insecticides containing E 605 must on no account be applied

TABLE II

THE EFFECT OF TEPP, E605, DDT, BHC AND NICOTINE ON *Armadillidium speyeri* IN SOIL

Substance	Concentration %	Woodlice killed %		
		24 Hours		5 Days
		Expt. 1	Expt. 2	Expt. 2
TEPP (40·3% tetraethyl pyrophosphate).	0·25	100	100	100
	0·125	100	95	100
	0·1	100	90	100
	0·067	55	70	95
	0·05	60	45	60
E 605 (Parathion), commercial ester, purity unknown.	0·2	100	100	100
	0·1	100	100	100
	0·05	60	100	100
	0·025	60	65	100
DDT—wettable powder—20% commercial DDT.	0·5	20	40	60
	0·25	15	15	60
	0·125	15	20	55
	0·07	40	10	35
BHC — dispersible solution — 3% gamma isomer.	0·5	100	90	100
	0·25	35	45	100
	0·125	40	35	45
Nicotine.	0·2	35		40
	0·1	60		15
	0·05	30		40
Untreated.		5	5	5
		0	0	0
		10	0	5

to the soil in which food crops are grown until it has been established that the chemical, which is highly poisonous to man, is not taken up by the plant.

REFERENCES

[1] HALL, S. A., and JACOBSEN, M., Agric. Chemicals, 1948, 3, 30.

[2] MARTIN, H., and SHAW, H., "Developments in methods and material for the control of plant pests and diseases." B.I.O.S., Final Report, 1095 (1946).

[3] EATON, J. K., and DAVIES, R. G., *Nature*, 1948, 161, 644.

IV. CHEMICAL PROBLEMS

1. NITRIFICATION STUDIES

O. OWEN and G. W. WINSOR

Experimental methods

Nitrogenous compounds to be tested were thoroughly mixed with the moist soil, and maintained at a constant temperature of 23° C. in glazed earthenware pots containing 1,500—2,000 grammes. The pots were covered with glass plates to reduce moisture losses, and very small additions of water made as required to maintain the original content. When sampling, the contents of each pot were turned out and mixed, 50—100 g. samples being taken. In the earlier part of the work nitrate was estimated colorimetrically by the phenoldisulphonic acid method. Reduction with Devarda's alloy and distillation into N/50 acid was later adopted. Ammonia was determined by the method of McLean and Robinson[1] (1924) and nitrite colorimetrically with the Griess-Ilosva reagent.

Response to level of application of fertilizers

In the 1947 report (fig. 1, p. 73) data were given for hoof and horn at three levels of application, showing that with this material the percentage nitrified was virtually independent of the amount added over the range 90—360 parts per million of nitrogen. This result was in direct contrast to those obtained for substances more rapidly transformed to nitrate in the soil, and was considered worthy of further experiment.

For the 1948 tests a sample of horn was used having a nitrogen content of 14·6 per cent. and ground to pass a 1 mm. sieve.

In the first experiment the soil used had the following analysis :—

Total nitrogen (Kjeldahl)	0·65 per cent.
Phosphoric acid (P_2O_5) (soluble in 1 per cent. citric acid solution)	0·039 per cent.
Potash (K_2O) (soluble in 1 per cent. citric acid solution)	0·016 per cent.
Organic carbon (Walkley and Black)	4·67 per cent.
Total carbonate, as calcium carbonate	2·99 per cent.
Initial nitrate content (NO_3-N)	76 p.p.m.
Initial moisture content	36·4 per cent.
pH	6·97

Horn was mixed with the soil in quantities corresponding to 150, 250, and 350 parts per million of nitrogen, the treatments at the two lower levels being duplicated. The amount of nitrate-nitrogen (NO_3-N) in any given sample, less that found in the control soil at the same date, has been expressed as a percentage of the total nitrogen added as horn and recorded as " percentage nitrified " in fig. 1. Very close agreement was in fact found between percentages nitrified at the three levels of application throughout the transformation. The amount of nitrate produced thus appears to be directly proportional to the quantity of horn added.

In the foregoing experiment the colorimetric method of analysis was employed. A similar experiment was made in which the Devarda reduction method was used. The soil was taken from a tomato house at the end of the season, and had the following analysis :—

Total nitrogen	0·31 per cent.
Phosphoric acid (P_2O_5)	0·26 per cent.
Potash (K_2O)	0·05 per cent.
Organic carbon	2·46 per cent.
Total carbonate ($CaCO_3$)	1·99 per cent.
Initial moisture content	18·5 per cent.
Initial nitrate content (NO_3-N)	25 p.p.m.
pH	7·51

Levels of application of the horn sample were again 150, 250, and 350 parts per million of nitrogen on the basis of dry soil. The results are recorded in fig. 2. Again it is found that the percentage nitrified at any one time was largely independent of the quantity of fertilizer added to the soil. In this respect the transformation of hoof and horn materials to nitrate seems to differ from substances more readily nitrified ; the latter, as exemplified by guano, urea, and ammonium salts, show widely

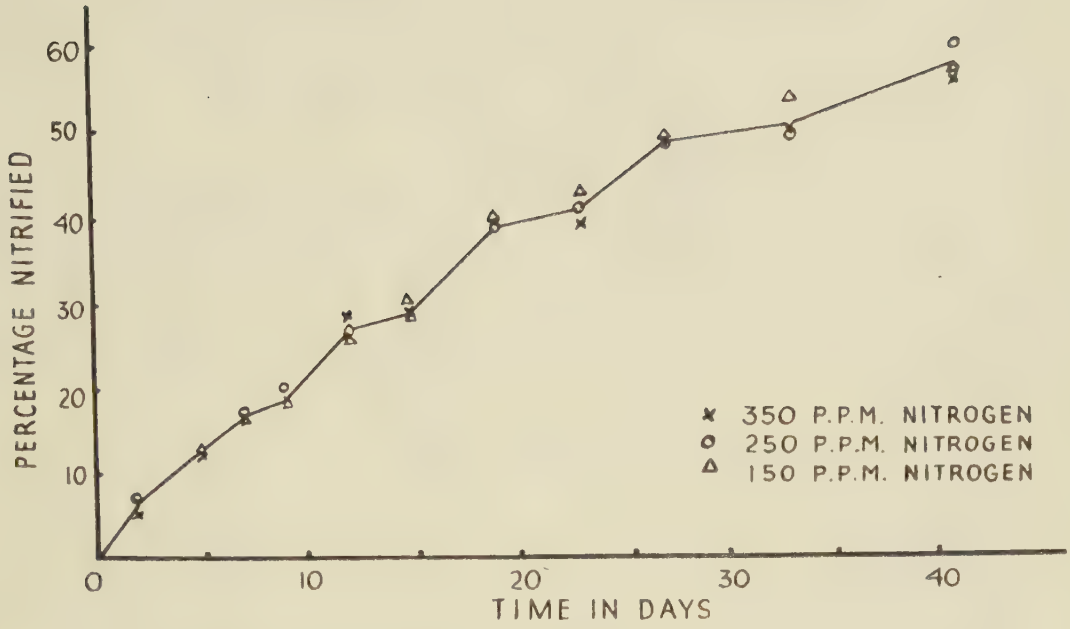


FIG. 1.—The percentage of horn nitrified at different levels of application corresponding to 150, 250, and 350 parts per million of nitrogen in the soil.

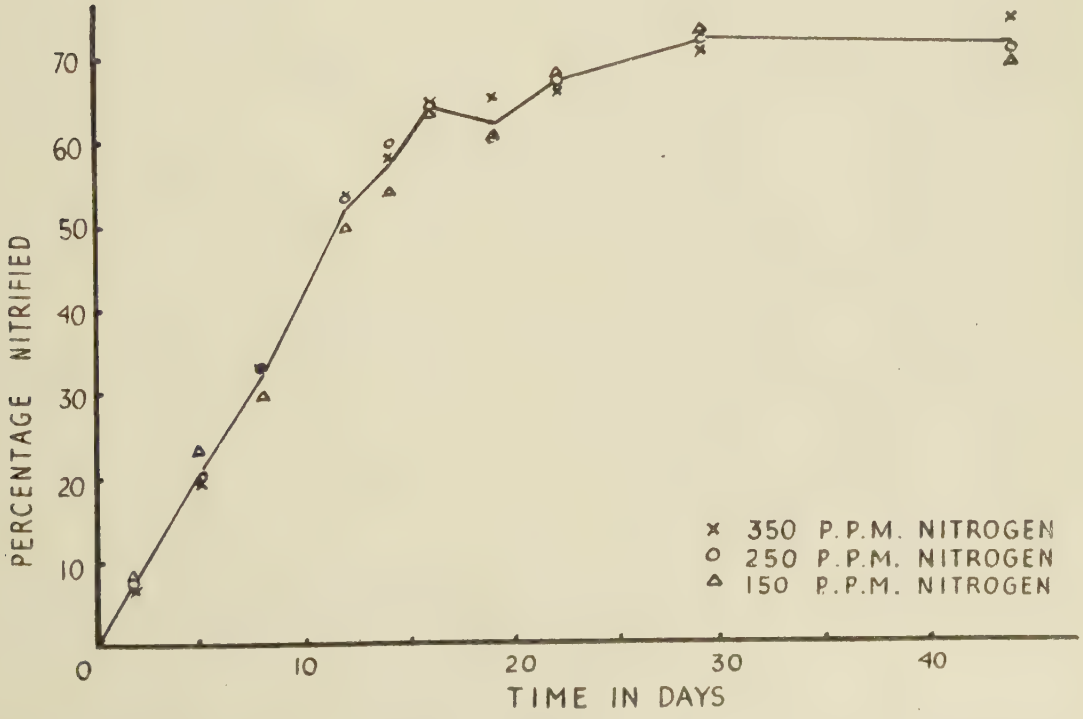


FIG. 2.—The percentage of horn nitrified at different levels of application corresponding to 150, 250, and 350 parts per million of nitrogen in soil taken from a tomato house.

different percentages nitrified over the same range of levels of application, the lowest application being most completely transformed under the conditions of the experiment (see Annual Report 1947, fig. 4, p. 79). It is possible, though as yet unproved, that a response to level of application of the type shown by hoof and horn is only found when the rate of attack by micro-organisms on the original substance is low in relation to that of the subsequent transformations to nitrate.

The effect of added carbon compounds on nitrification

It is well known that the transformation of nitrogenous compounds to nitrate in the soil by micro-organisms is markedly influenced by their carbon/nitrogen ratios (C/N). By using ammonium salts as a source of nitrogen and adding varying amounts of a carbon compound it is possible to produce a wide range of mixtures having different C/N ratios ; the distinction between these mixtures and compounds such as proteins containing both carbon and nitrogen in the same molecule must however be emphasized.

Three series of nitrification experiments with mixtures of ammonium sulphate and phosphate and starch have been made. Analyses for ammonia have been included in two of these experiments, and for nitrite in one.

(1) Transformation of ammonium sulphate in a market garden soil.

The soil used in this experiment had the following analysis :—

Total nitrogen	0·30 per cent.
Phosphoric acid (P_2O_5)	0·31 per cent.
Potash (K_2O)	0·019 per cent.
Organic carbon	2·41 per cent.
Total carbonate	1·30 per cent.
Initial moisture content	23·0 per cent.
Initial nitrate content	14 p.p.m.
pH	7·0

Ammonium sulphate was added to the soil in quantities corresponding to 300 p.p.m. of nitrogen. In addition one batch of soil received starch corresponding to 0·1 per cent. on the basis of dry soil, and a further batch corresponding to 0·3 per cent. The control soil received neither ammonium sulphate nor starch. The approximate carbon/nitrogen ratios (C/N) of these added mixtures of starch and ammonium sulphate are 1·5 and 4·4 respectively. Data for both ammonia-nitrogen (NH_3-N) and nitrate-nitrogen (NO_3-N) are plotted as parts per million difference from control in fig. 3. The data for ammonia show a very marked effect due to the presence of a source of carbon ; the presence of the latter causes a more rapid disappearance of ammonia. For the nitrate figures the most important result is the variation between the amounts of nitrate found in the soils at the end of the experiment, the presence of the carbon compound reducing the extent to which nitrate appears in the soil. The recovery of added nitrogen as ammonia and nitrate varied over the range 84 –96 per cent. in the first two weeks of the transformation of ammonium sulphate in absence of added starch. Direct comparison of recovery figures for treatments including starch is not possible from the present data, but the sum of ammonia-nitrogen and nitrate-nitrogen is clearly decreased in presence of the source of carbon. It is possible that the difference is due to nitrogen assimilated by the micro-organisms and is related to their numbers.

(2) Transformation of di-ammonium hydrogen phosphate ($(NH_4)_2HPO_4$) in the soil.

In this experiment the market garden soil was again used, with ammonium phosphate supplying nitrogen corresponding to 300 p.p.m. on the basis of oven-dried soil. Starch was added in quantities corresponding to 0·15, 0·25, and 0·35 per cent., all treatments being duplicated. Analyses for ammonia-nitrogen and nitrate-nitrogen are given in Table I as increase above the control soil. Actual nitrate-nitrogen values are also given for the control soil, but these have been omitted for the ammonia, being relatively low (4·3 p.p.m.). Nitrite data (NO_2-N) are recorded as actual parts per million in treated and untreated soil.

As in the preceding experiment it will be seen that as the amount of added starch is increased the amount of nitrate found in the soil at the end of the experiment is decreased. Similarly the extent to which ammonia disappeared from the soil in a given time was increased by the presence of starch. The analytical data for nitrite are only of interest in that they show that nitrite does not accumulate in this soil, only a very small increase being found after treatment with the ammonium salt.

(3) A third experiment was conducted on the lines of the previous two, but using the Devarda method for estimation of nitrate in place of the colorimetric technique. The results are in agreement with those already found.

The extension of the investigation of carbon/nitrogen ratios to a series of fertilizers and pure

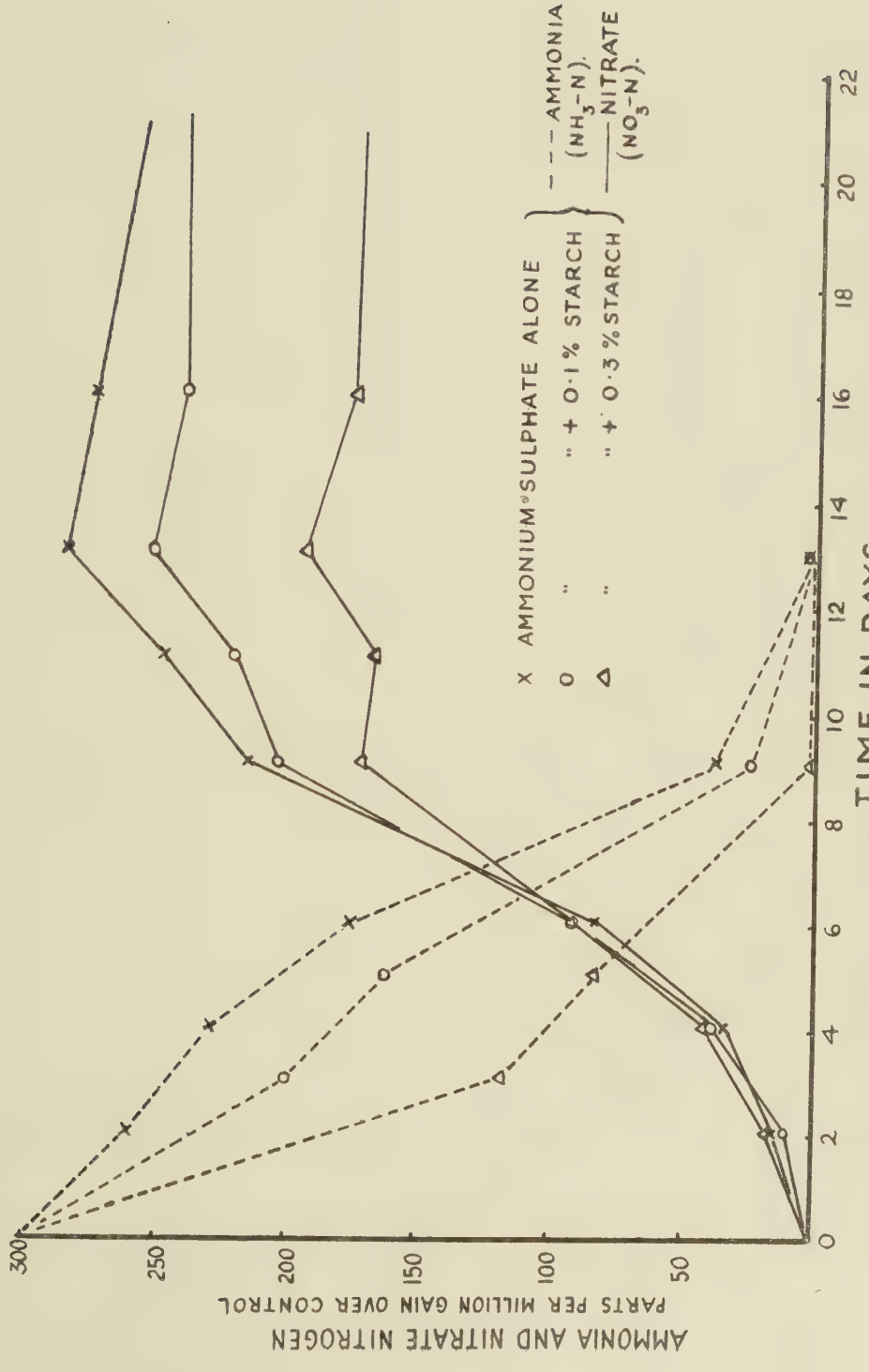


FIG. 3.—The effect of an added carbon compound (starch) upon the nitrification of ammonium sulphate.

TABLE I

Days:	1	2	3	4	5	7	8	9	10	11	12	14	16	19	22
Treatment	Nitrate-nitrogen, parts per million increase above control														
$(NH_4)_2HPO_4$	—	—	19	33	50	91	124	158	195	230	256	292	261	372	254
„ 0·15% starch	—	10	14	33	62	95	123	154	183	209	234	249	234	—	211
„ 0·25% „	—	5	20	38	53	94	124	145	173	197	203	222	206	206	188
„ 0·35% „	—	0	13	35	56	80	121	138	162	173	178	147	181	199	174
Control Soil (actual) ...	26	28	29	24	28	32	29	27	30	31	33	25	35	37	30
	Ammonia-nitrogen, parts per million increase above control														
$(NH_4)_2HPO_4$	295	280	252	230	212	168	143	111	78	49					
„ 0·15% starch	263	219	197	176	158	122	98	74	53	28					
„ 0·25% „	266	190	154	144	124	93	89	50	26	13					
„ 0·35% „	253	191	116	117	95	75	48	34	11	3					
	Nitrite-nitrogen, parts per million														
$(NH_4)_2HPO_4$	0·5	0·6	—	0·5	—	0·3	0·2	—	0·2						
„ 0·15% starch	—	—	0·6	0·5	—	0·3	0·2	—	0·2						
„ 0·25% „	0·3	—	0·6	0·5	—	0·4	0·2	—	0·2						
„ 0·35% „	—	—	0·5	0·7	—	0·4	0·2	—	0·2						
Control Soil	0·1	0·1	0·3	0·1	—	0·2	0·1	—	0·2						

compounds containing both carbon and nitrogen introduces complicating factors. In the preceding experiments the amount of nitrogen added to the soil and its chemical form were both constant for any of the series, and the carbon compound, though added in different quantities to produce a range of C/N values, was itself of the same chemical form throughout. When a series of nitrogenous organic compounds is compared on the basis of nitrate formation in the soil, not only does the C/N ratio vary but the chemical complexity of the materials differs. It is known that when proteins are decomposed by micro-organisms in the soil a complex series of reactions occurs which may be partly represented in simplified form by the series :—

$$\text{Protein} \rightarrow \begin{Bmatrix}\text{Proteoses}\\\text{peptones}\end{Bmatrix} \rightarrow \text{amino-acids} \rightarrow \text{ammonia} \rightarrow \text{nitrite} \rightarrow \text{nitrate.}$$

It is therefore clear that during the nitrification of a range of materials such as proteins, peptone, amino acids and ammonium salts the actual chemical transformations involved differ widely in extent. Furthermore the chemical nature of the intermediate and final products, together with other factors such as the solubility and perhaps surface area of the starting material, may be expected to influence the rates of reaction.

A comparison of nitrogenous substances of different carbon/nitrogen ratio and chemical complexity is at present being made on the basis of formation of nitrate in several soils. The results will be presented in a later report, but one preliminary experiment on the nitrification of dried blood, two amino acids, and an ammonium salt is described below.

Dried blood, tyrosine, glycine and ammonium sulphate were added to the market garden soil (analysis previously given) in quantities corresponding to 300 parts per million of nitrogen calculated on the basis of oven-dry soil. The initial moisture content was 23·3 per cent. All treatments except tyrosine were in duplicate. Mean values for increase in nitrate-nitrogen over the control soil are plotted against time in Fig. 4.

Of the two amino acids used glycine has the relatively simple formula $CH_2(NH_2)COOH$, while tyrosine has a more complicated structure $HO.C_6H_4.CH_2.CH(NH_2).COOH$. Values for carbon and nitrogen content of the materials used, with the exception of the carbon content of the dried blood sample which is not yet available, are given in Table II together with the maximum values for nitrate found in the soil during the experiment.

TABLE II

Material	% Carbon	% Nitrogen	C/N Ratio	Maximum % Nitrified
Ammonium Sulphate ...	0	21·2	—	95
Glycine	32·0	18·7	1·71	88
Tyrosine	59·6	7·74	7·70	62
Dried Blood	?	13·3	?	60

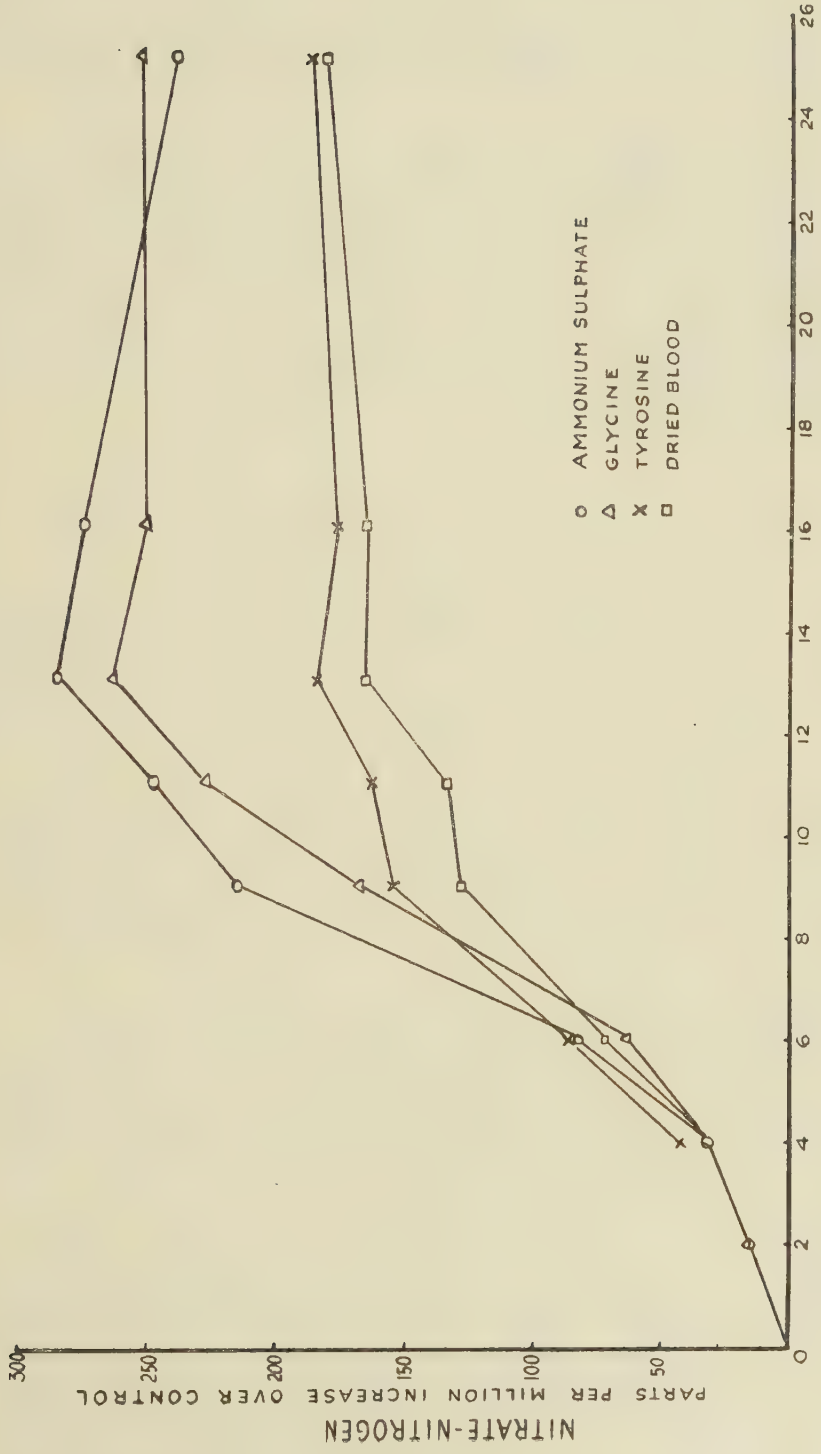


FIG. 4.—The nitrification of four substances differing in carbon/nitrogen ratio and in chemical complexity.

From Fig. 4 and Table II it will be seen that the presence of carbon in the nitrogenous material added to the soil markedly reduces the extent to which nitrates are present in the soil in the later stages of the experiment. In the case of the two amino acids the higher C/N ratio was associated with the lower percentage nitrified. More extensive experiments on similar lines are in hand, and attention is being given not only to the maximum values found at the end of the decomposition but also to the initial stages where the complexity of the nitrogenous materials might be expected to influence the rates of reactions.

Comparison of the rates of nitrification of blood, hoof and horn fertilizers

In the Annual Reports for 1946 and 1947 experiments were recorded in which samples of dried blood and of mixed hoof and horn were compared. Contrary to expectation it was found that the hoof and horn sample, taken from the nursery stocks in 1946, was at least as readily nitrified as the dried blood, sometimes more so. In a further experiment with these materials two samples of hoof and of horn separately were included. Each material was added to the market garden soil in quantities equivalent to 300 parts per million of nitrogen on the basis of dry soil, the treatments being duplicated. The soil moisture at the start of the tests was 23·4 per cent. The analytical data are recorded in Table III as increase in nitrate-nitrogen above control, ammonium sulphate being also included as a standard for comparison. The actual nitrate-nitrogen values for the control soil are given in the bottom line of the table.

TABLE III

Days:	2	5	7	9	12	14	16	20	26	36	47
	Nitrate-nitrogen, parts per million										
Dried Blood	11	53	104	144	153	155	156	148	190	175	—
Hoof and Horn	19	84	131	143	153	163	165	148	184	170	—
Hoof	19	61	83	97	113	119	122	140	169	166	188
Horn	15	18	33	67	80	91	93	101	127	124	147
Ammonium Sulphate ...	9	55	149	243	247	261	271	266	292	253	—
Control Soil	8	8	11	12	15	19	21	21	27	32	29

As in previous experiments this particular sample of hoof and horn was more rapidly nitrified than the dried blood at the start of the experiment, after which the two sets of data were very similar. The separate samples of hoof and of horn were however distinctly slower than the mixed hoof and horn material. It was subsequently learned that the mixed sample had been " calcined " by the manufacturer whereas the separate samples had not. The results suggest that some investigation of the effect of heat treatment upon hoof and horn materials would be of value.

Examination of analytical methods for the estimation of nitrate

The phenoldisulphonic acid method for the colorimetric estimation of nitrate is found in numerous text-books and research publications. Numerous variations in the actual analytical procedure are however found, and opinions as to the accuracy of the method and the precautions necessary in soil extracts are somewhat conflicting (see for example Roller and McKaig [2] (1939), and Berge [3] (1941)). It was therefore considered necessary to make a further examination of the colorimetric method as applied here to the relatively rich soils of the nursery, and a direct comparison with the Devarda reduction method was accordingly made throughout a complete nitrification experiment with five fertilizers.

For this experiment a tomato soil was used (analysis previously given), the fertilizers being added to the soil in quantities equivalent to 300 parts per million of nitrogen on the basis of oven dry soil. Analytical data for the colorimetric and reduction methods are compared in Fig. 5, the apparent increase in nitrate-nitrogen (NO_3-N) being plotted against time in days. The colorimetric data have been shown as isolated points, while the lines on the graph refer to the reduction method. It is considered that the results are in very fair agreement, though certain discrepancies are found, particularly at the start of the decomposition. In further confirmation the Devarda reduction method has been used to repeat the main experiments of the earlier work. Thus the effect of starch upon the nitrification of ammonium salts and the relation between level of application of horn and percentage nitrified have both been verified. It is therefore concluded that no serious inaccuracy has resulted from the extensive use of the rapid colorimetric method in the earlier work. Several

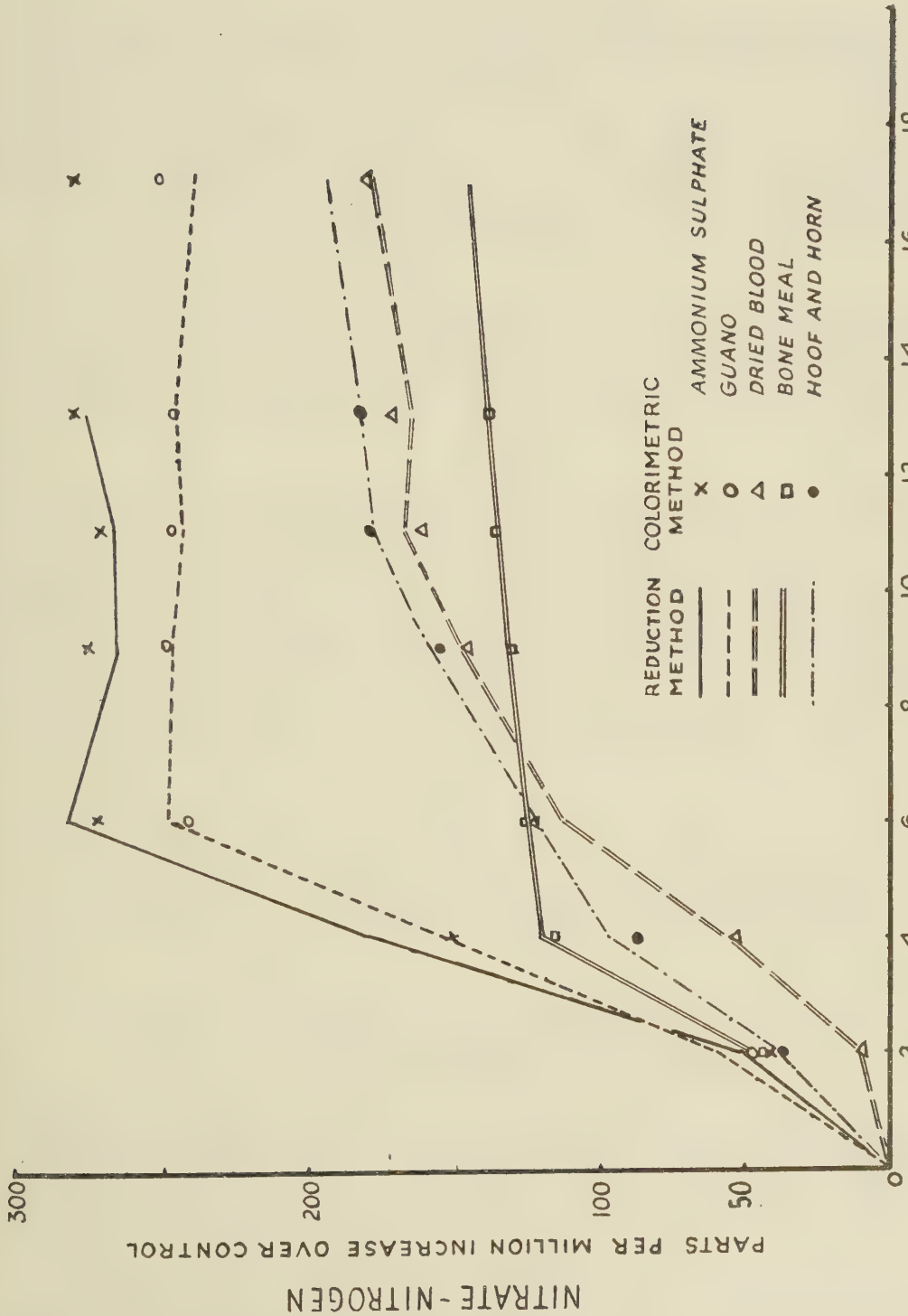


FIG. 5.—Comparison of the colorimetric and reduction methods of analysis throughout the nitrification of five fertilisers. The colorimetric data have been plotted as isolated points, while the lines refer to the reduction method.

sources of error can however arise in the colorimetric procedure, and the reduction method alone will be used in the continuation of this investigation.

The decomposition of urea on distillation with magnesia

In Table XI, page 80 of the 1947 Annual Report, results were presented for the liberation of ammonia from urea and other materials by distillation from an aqueous suspension of magnesia. Professor H. Nicol has since very kindly drawn our attention to the work of Quarteroli[4] (1947) on the decomposition of urea. Re-examination of our own data for urea has revealed an arithmetical error in the figure given as 60-70 per cent. ; this should have been 6—7 per cent. In further experiments we find that the extent of the decomposition varies not only with the period of distillation but with the amount of urea taken. Thus on collecting 250 mls. of distillate the following values for percentage of the total nitrogen liberated as ammonia were obtained :—

Urea	Percentage N liberated as ammonia
0·15 g. ..	7·79
2·00	5·05

We are very grateful to Professor Nicol for calling our attention to this error.

Acknowledgments

We wish to acknowledge the assistance of Mr. L. D. Woollard, B.Sc., A.R.I.C., in the analytical work on which Tables I, II and III and Figs. 3 and 4 are based.

We also express our gratitude to Thos. Elliott Ltd. for generous samples of some of the materials used.

Summary

The transformation of nitrogen in fertilizers and other nitrogenous compounds to nitrate in the soil has been the subject of further investigation on the lines indicated in the Annual Reports for 1946 and 1947. Data for the relation between level of application and percentage nitrified for horn are in agreement with those reported in 1947. The influence of added carbohydrate on the nitrification of ammonium salts has been studied, and the extension of this work to organic nitrogenous compounds of known carbon content is planned. During the year the colorimetric method for determination of nitrates, as used at the start of this work in 1946, was critically examined with regard to recovery of added nitrate in nursery soils. Direct comparison of colorimetric results with those of the Devarda reduction method throughout the course of nitrification of five typical fertilizers showed no serious discrepancies, but the colorimetric method is less accurate than was originally thought. The reduction method has been used to confirm the main results of the earlier work, and will in future be adopted for all determinations.

References

[1] McLean, W., and Robinson, G. W., *J. Agric. Sci.*, 1924, 14, 548-554.
[2] Roller, E. M., and McKaig, N., *Soil Science*, 1939, 47, 397.
[3] Berge, T. O., *Soil Science*, 1941, 52, 185.
[4] Quarteroli, A., *Annali della Facolta di agraria*, Univ. Pisa, 1947, 8, 209-240.

2. THE USE OF ALGINATES AS A SOURCE OF ORGANIC CARBON IN SOIL

O. OWEN

The success of sodium alginate as a possible source of organic carbon in propagating soils for tomatoes made it desirable to consider whether other alginates would be as effective. Accordingly extensive trials have been carried out on tomato seedlings and young plants in which the sole source of added organic matter has been one of the following :—sodium alginate, alginic acid, calcium alginate, ammonium alginate.

In all experiments the results have been compared with those produced in the John Innes composts and in the standard mixture used at this Station in which the added organic material consists of stable manure.

It was assumed that in some soils, at all events, the decomposition of the alginate might be accompanied by the denitrification which frequently develops when organic matter decomposes

quickly in soil in the absence of added nitrogen. Accordingly in all trials a fairly liberal amount of nitrogen in the form of hoof and horn has been used in the composts. One of the effects of this has been to produce a rather soft type of plant in the pot at the planting out stage. That this condition is in no way undesirable is suggested by the fact that when such plants have been planted in the borders they soon become indistinguishable from plants raised in ordinary composts.

For sowing, the mixtures have consisted of steamed maiden loam plus one half or one per cent. of the alginate to which are added 8 ozs. of lime and 10 ozs. superphosphate per hundredweight. For potting, the same mixtures have been used with the addition of 8 ozs. per hundredweight each of sulphate of potash and hoof and horn.

The ealier tests showed that a better effect was produced on some soils with one per cent. of alginate than with the smaller quantity. Accordingly the lower dressing was omitted from later trials.

The main results of small scale experiments may be summarized briefly as follows :—

Ammonium alginate

This compound invariably delayed germination in all the soils tested. Subsequent growth of the seedlings was retarded. The foliage was stunted and of a very dark green—almost blue—colour. Frequently some scorching of the cotyledons and leaves occurred. A similar effect is sometimes observed in steamed soils when ammonium salts are added and it is concluded that the effects observed are due to excess of ammonia.

On this account the use of this compound has been suspended for the time being.

Sodium alginate

This compound has been satisfactory in all tests : seedlings and young pot plants have been as good as or better than those in either of the standard mixtures used as a basis of comparison.

Alginic acid

The effects of this compound are the same as those observed with sodium alginate. In some trials the one compound has given slightly better plants while in others the reverse has been the case. In general it is concluded that from a commercial point of view there is little to choose between them.

Calcium alginate

This compound behaves in what is almost an anomalous way. If a mixture is used for sowing immediately after preparation it frequently happens that, when the seedlings are at the first rough leaf stage they are smaller and darker in colour than their counterparts in mixtures containing alginic acid or sodium alginate. On this standard the compound would therefore be rated inferior to the other two. If, however, the seedlings are allowed to remain in the boxes an acceleration in the rate of growth develops eventually so that by when the second pair of leaves are defined seedlings in the calcium alginate mixture are as large as or larger than those in the other mixtures. In fact in most trials where growth is allowed to develop to a late stage the calcium alginate mixtures give the best results.

In 60's the same order of events occurs but the effects are even more pronounced. In a batch of some 200 plants potted into a mixture as soon as it had been prepared growth was very uneven. About half the plants made growth apparently normally and progressively during the four weeks they were under observation. The remainder of the plants, however, grew at quite different rates. All of them suffered some retardation. Many were definitely stunted and under ordinary commercial conditions might have been discarded after a few days. At the end of a fortnight there was noticeable improvement in many but by no means all of them. At the end of three weeks about 10 still remained dwarfed and were of a poor, pale colour. During the ensuing week end, however, even these started to grow, and thereafter made abnormal progress with the result that on the 30th day after potting all the plants were sufficiently satisfactory to be planted out. It should be added, however, that they were not all uniform in size. They were, in fact, planted out in borders and at the time of reporting were all making normal and apparently uniform growth.

These results have been described in some detail for this particular soil. On other soils similar results were observed but in a very much less degree and the early depression in growth rate has been barely perceptible. In any case it has usually happened that the final product in calcium alginate mixtures has been as good as in any other treatment.

Tests on commercial nurseries

The results obtained under controlled experimental conditions appeared to justify trials under ordinary commercial conditions. Accordingly a number of growers kindly undertook to try calcium alginate on a small scale during the normal propagating season. Seeds were sown and seedlings potted up in the mixtures already described and containing 1 per cent. calcium alginate. The results at the centres were somewhat mixed as the following summary shows :—

Centre 1. No difference between seedlings and plants at any stage and those raised in the usual way.

Centre 2. Treatment a complete failure. Germination was delayed and reduced and it was not considered worth while potting the seedlings.

Centre 3. Seedlings and plants in pots definitely better than those produced with normal mixtures.

Centre 4. Seedlings and plants slightly inferior to normal plants but quite satisfactory.

Centre 5. Germination delayed and seedlings stunted at first. They made partial recovery but were always inferior to plants with normal treatment.

Centre 6. Seedlings and plants slightly inferior to normal plants but quite satisfactory.

Centre 7. Seedlings definitely better than normal ones. At planting out stage plants superior to normal ones.

At Centres 1, 2, 3 and 5 the normal mixtures were the John Innes composts. At Centre 4 the normal mixtures were very rich containing old cucumber soil in addition to stable manure. At Centre 6 the mixtures were very rich containing a high proportion of stable manure. At Centre 7 the mixtures contained about 25 per cent. (by volume) old cucumber border and 20 per cent. stable manure.

These results raise interesting considerations. Of the three compounds likely to prove of use only sodium alginate is soluble. We have never applied it as a solution but as in the case of the other two compounds we have mixed the dry powder intimately with the soil before wetting. That this solubility is of no immediate advantage is suggested by the fact that both alginic acid and the sodium salt show the same order of activity as measured by the growth of young tomato plants. It is known that alginic acid decomposes comparatively quickly in soil and presumably the products of such decomposition are responsible for the effects observed. By the same precept alginates are decomposed. In the case of the sodium salt the products of decomposition are beneficial or at worst innocuous. All the indications are, however, that the first effects of the decomposition products of calcium alginate are harmful, which rather suggests that the type of decomposition differs from that of the other two. As such decomposition is the result of microbiological activity it follows that its effects will vary from soil to soil and even from time to time in the same soil. These effects as we have seen have already been observed in the experimental results now described.

In view of the results recorded at Centres 2 and 5 we are unable at this stage to make an unqualified recommendation of the use of calcium alginate.

Summary

This work has been extended to include alginic acid, calcium aginate and ammonium alginate. The last-named is definitely harmful to tomato seedlings and has been discarded. Alginic acid has the same order of effectiveness as sodium alginate. Calcium alginate appears to take longer to decompose in the soil than do the other compounds. In some soils the first effect may be to depress the rate of growth. This effect is followed by an accelerated rate with the result that eventually the plants in composts containing calcium alginate have often proved best in comparative trials. Trials under commercial conditions on nurseries have been carried out with calcium alginate.

Acknowledgments

Grateful acknowledgements are made to Alginate Industries Ltd. for supplies of some of the materials used in this work.

3. SOIL STERILIZATION STUDIES

J. N. DAVIES and O. OWEN

Nitrate-nitrogen has been estimated in soil extracts by the Devarda reduction method and ammoniacal-nitrogen by the method of McLean and Robinson (1).

A cucumber border in one of the houses has been examined. This was sterilized by the Hoddesdon Pipe system with the pipes ten to twelve inches deep. A temperature of 212° F. was maintained

for 20 minutes. Before sterilization the nitrate content was high at 240 p.p.m. On the second day after steaming this had risen to 285 p.p.m. Thereafter the value increased steadily up to the tenth day when it was 325 p.p.m. There were fluctuations from then until the twenty-seventh day when a maximum value of 372 p.p.m. was recorded. After that further fluctuations occurred and the value on the seventy-seventh day was 329 p.p.m. An adjoining plot which was not steamed showed variations in nitrate contents, a minimum value of 196 p.p.m. being observed on the tenth day and a maximum of 289 p.p.m. on the seventy-seventh day.

Before sterilization ammoniacal-nitrogen concentration was less than 1 p.p.m. On the second day after steaming this had risen to 30 p.p.m. Values fluctuated between 26 p.p.m. and 46 p.p.m. for the succeeding nine weeks, but even on the seventieth day the value was still 42 p.p.m. Meanwhile the concentration in the unsteamed plot adjoining had never been above 4·6 p.p.m.

It should be mentioned that throughout this period sampling was actually carried out on all occasions in the cucumber house itself where all the usual preparations for planting cucumbers were taking place. Consequently there was the possibilitiy, nay, likelihood, of reinfection of the sterilized soil by organisms likely to affect both ammonification and nitrification.

Some of the soil from the same house was sterilized in a steaming model used in the laboratories. The intention was that changes in the soil should be followed under conditions differing from those in the cucumber house. Accordingly the steamed soil and its unsteamed counterpart were kept in glazed earthenware jars in a thermostatic chamber maintained at 23° C. Each jar was covered by a glass plate to reduce, but not eliminate, evaporation and the opening at the base of each jar was plugged loosely with cotton wool to prevent the soil from coming out. Under these conditions the nitrate-nitrogen content of the steamed soil which originally was 250 p.p.m. fluctuated between 228 p.p.m. and 243 p.p.m. during thirty days. This is in sharp contrast to the behaviour of the soil in the house itself. The unsteamed soil showed values between 243 p.p.m. and 262 p.p.m. during the same period.

Under the same conditions and at the same time the ammoniacal-nitrogen level, originally 3 p.p.m., fluctuated between 38 p.p.m. on the seventh day and 53 p.p.m. on the thirtieth day after steaming. The ammoniacal-nitrogen concentration on the unsteamed soil never rose above 2.8 p.p.m.

No attempt was made to keep these soils sterile, in fact they were turned out of their respective jars for sampling. It may be considered that under these conditions the possibility of reinfection is less than in a glasshouse and this might account for the fact that no increase in nitrate production has been observed. At the same time there is still the decided increase in ammonification to be accounted for.

Somewhat similar behaviour was observed in a maiden loam. This had been stacked in the open and was being broken down and sterilized in bins. In this case an initial nitrate-nitrogen concentration of 29 p.p.m. rose to 35 p.p.m. one day after steaming and to 47 p.p.m. on the twenty-second day, while in the unsterilized soil it remained at 31-32 p.p.m. An initial ammoniacal-nitrogen concentration of 5 p.p.m. was increased to 14 p.p.m. one day after steaming and to 146 p.p.m. after twenty-two days. In the unsterilized soil the value fell from 5 p.p.m. to 1·6 in twenty-two days. Here again no special precautions were taken and there were opportunities for re-infection to take place.

Summary

Towards the end of the year work was begun on the chemical effects of the sterilization of soil by steaming. The data obtained so far confirm what is generally known, namely, that under commercial conditions both nitrate and ammonia production are increased.

Reference

[1] McLean, W., and Robinson, G. W., *J. Agric. Sci.*, 1924, 14, 548.

4. THE EFFECT OF SOME ACUTE MINERAL DEFICIENCIES ON GLASSHOUSE PLANTS

J. H. L. MESSING and O. OWEN

Asparagus plumosus nanus

For this experiment plants six to seven inches high each having three small fronds open were selected for uniformity in size and habit and transferred from soil to the sand on July 22nd after their roots had been carefully watered with distilled water. From then onwards the plants were watered with dilute nutrient solutions identical in all respects except for the omission of the element in question.

For control purposes four plants were fed with a complete nutrient solution. To wash out the element in question from the sand no solution was collected for re-use for the first two months. Growth of the control plants was very satisfactory all through the thirty weeks with which the report deals.

No Nitrogen

The effect was general throughout the whole plant, no special part being affected. Loss of colour became noticeable after eight days and after three weeks the colour had faded to a very pale green. Very little growth took place except in the first three weeks of the experiment and the plant remained practically at a standstill. No shedding of needles took place and no dying of any part of the plant was observed until the time of reporting, thirty weeks after the commencement of the experiment.

No Phosphorus

No characteristic effects or markings were noticed. The rate of growth was much slower and the green colouring was dull, less vivid and somewhat darker than that of the control plants. The plant was noticeably stunted from six weeks onwards and very few new shoots emerged. No part of the plant was observed to die during the period of the experiment.

No Potassium

For the first fifteen weeks the only noticeable effect was a slightly slower rate of growth. The relative excess of nitrogen manifested itself in the darker green colouring of the fronds.

In the sixteenth week some of the older needles in the centre of the frond turned yellow and then dark brown. This symptom worked slowly along the shoots outward towards the edges of the frond. At the end of a month the whole frond was affected and needles were falling. In the meantime the same symptoms had appeared on the other fronds and were spreading rapidly. Seven weeks later some of the first fronds to be affected were quite bare, others were brown in the middle with the tips still green, and in some the trouble had only just started. The younger fronds were still apparently not affected at all.

At this stage the effect of prolonged potassium deficiency seemed to be acute as new shoots were thinner, and after growing for some time turned yellow. This colour is most pronounced immediately above the soil level. Finally the whole shoot turned yellow, then light brown, and died without opening, after attaining a height of ten to twelve inches.

No Calcium

The effects of this deficiency were very acute. Little growth occurred and the new shoots were short, all expanding at the same level. After four to five weeks the plant became light green in colour and there was a characteristic change in shape of the leaf as a whole. The length of the main shoot was reduced and instead of conforming to the shape of an isosceles triangle the apex became definitely blunted and the whole leaf took on the shape of a turfing tool. Both the ends of the stems and the needles on them turned greyish brown and died. No dying back occurred, however, to any considerable extent. After about seven weeks no new shoots grew more than $1\frac{1}{2}$ inches above the sand. The growing tip died in each case, first becoming flat and pinkish-violet immediately below the tip, and then turning dark brown and dying back to the sand level. New shoots continued to appear at almost the same rate as on controlled plants but their life was a very short one.

No Magnesium

There were three different periods of response when this element was withheld. During the first three weeks plants were normal and the rate of growth was not affected. During the next two or three weeks chlorosis developed slowly, mainly in the older parts, but the effect on the growth was still small. During the third period the plant suddenly turned yellow, then light brown, and the needles were shed rapidly. From this stage there was no further growth and the plant died slowly.

The older growth is affected first, the youngest shoots and their top parts remaining alive the longest, presumably due to the re-utilization of magnesium. The yellowing and the dying and falling off of the needles proceed on each frond from the edges toward the centre. By the end of December not much more than the dead, yellowish brown branches remained.

No Boron

This deficiency produced the most pronounced effect of all. The first symptoms were very similar to those associated with the omission of calcium. The plants turned yellowish green in

about three weeks. Only one new shoot managed to stand from the time the treatment started. Dying of stems and needles on the edges of the fronds had begun to take place within four to five weeks, but it did not spread inward to any great extent and the triangular shape of the fronds was maintained.

The growing tips of all shoots which emerged subsequently died in a matter of a few days and no shoot reached more than 2½ inches in height as compared with 1½ inches in the case of no calcium, the main difference being the way in which the growing tip died. In this case first it turned yellow and then light brown, the top inch being affected. The shoot remained in this state without any dying back occurring. In the thirtieth week of the experiment the lower 1½ inches was still green in some cases and yellow in others. In the case of the no-calcium plants the dead, dark brown shoot collapsed completely.

No Iron

No difference between this treatment and the control was noticeable until the end of November when some of the new growth showed a slightly lighter colouring. Growth also became a little less vigorous and the new shoots a little thinner than in the case of the plants where a complete nutrient was supplied. All these symptoms were very slight and difficult to assess bearing in mind the individual variations between similar plants grown under exactly the same conditions.

No Manganese

Growth in this case was perfect and in general the plants compared favourably with the controls. At the end of November dying of the tips of stems and the needles on the edges of some of the expanded fronds was observed. By mid-December the growing tips of two out of five vigorously growing trails had turned yellow and died. This was where they had reached a height of about three feet. The other three trails, however, were growing perfectly well, as were the new shoots. After the thirty weeks of the experiment the plant remained similar to the controls with the exception of the symptoms just described.

Chrysanthemums

Established cuttings of the varieties Rose Harrison, Bronze Harrison, and Imperial Pink were used. Treatment started on July 13th.

No Nitrogen

The first indications of this deficiency were apparent about a month after the treatment began and consisted of a loss of colour in older leaves and a reduction in size of younger ones. As the younger leaves developed they assumed an erect position and acquired a pale colour. Later the older leaves became more yellow with pigmentation of the margins. The whole range of colours, from slightly yellowish green on the top, through yellow green in the middle to yellow and yellow with red pigment in the case of the oldest leaves could be seen together on one plant. The lowest leaves were turning brown and dying. Both the Harrison's and the Imperials behaved similarly, the Imperial showing the symptoms a few days later than the Harrison's.

After 11 weeks necrotic spots along the mid-rib and the secondary veins were noticed on the uppermost leaves of the Harrison but these did not appear at all in the case of the Imperial. On the other hand, a red coloration of the older leaves was observed in the Imperial only. Flowering was delayed for about two weeks and the flowers were very small. At the time of flowering a few of the uppermost leaves were still green, all the others being brown and dead.

No Phosphorus

The difference between the plants receiving the treatment and the controls only became apparent after about two months. Then the plants became stunted, leaves were narrower than normal, dark green in colour and set at an acute angle to the stems. A month later the lower leaves turned yellow, then brown and finally died. This symptom was progressing rapidly up the plants and when the flowers opened only the top leaves were green and alive. Here again red pigment appeared on the yellowing leaves of the Imperial variety only. This might be due to the different genetical make-up of these two varieties. Flowering was very much delayed and when, at the end of November, plants were cut for analysis they were the only ones not fully opened, showing a delay of some three weeks.

No Potassium

The first symptoms of deficiency were noticed at the end of two months when a little mottling occurred on the middle leaves. The rate of growth slowed down at this stage and two weeks later

the plants were definitely stunted. Later still, brown spots appeared on the yellowish areas of the mottled leaves. At the same time the margins of most of the leaves rolled inwards and downwards. The spots grew bigger and the areas of the dead tissue, irregular in shape and dark brown in colour, were spread all over the middle leaves. The older and younger leaves however, escaped injury and retained a good green colour though of a slightly darker shade than that of normal leaves. Bud formation seemed to be accelerated and the plants undergoing this treatment were the first to produce fully developed flowers, though these were smaller, especially in the case of the Imperial, than those of the controls. The Imperial was, in general, more affected by this deficiency than the Harrison. Practically no death of the bottom leaves occurred.

No Calcium

The first symptom of deficiency appeared within 16 days in the Harrison and five days later in the Imperial. The leaves, particularly the younger ones, showed a slight loss of colour and two days later brown spots, irregular in shape and mostly scattered along the margins appeared on the top leaves. The youngest leaves showed a brown discolouration practically all round the margins and curled downwards a little. The spots on the top leaves grew rapidly and in a week's time the whole of the top surface was affected and the leaves were dead. Growing tips died and dying back of the stems took place, so at the end of the season only a few of the oldest leaves on each plant were still green. On both Rose and Bronze Harrison the leaves immediately under the dead ones were still growing and were even bigger than the corresponding ones on the controlled plants. This effect, however, was not observed on the Imperial. In addition to this difference and that of the five days' difference in appearance of the first symptoms mentioned above, the first spots on the Imperial were smaller and much darker and of slower growth.

No Magnesium

At the end of August a slight general loss of colour was observed, also an intervenal mottling of the lower leaves, this symptom being most pronounced on the middle leaves. Growth was not affected at this stage. The loss of colour did not become more pronounced until the beginning of October when small, still lighter spots appeared, on the oldest and middle leaves. These spots were visible when the leaf was examined against the light. Necrosis then set in, and the spots turned rusty brown, and increased in size while keeping their circular shape but were confined to the interveinal parts of the leaf which still remained green close to the mid rib and main veins. It was characteristic that the apex of the leaf blade retained its dark green colour longer than any other part and could be found in this condition even at this advanced stage. By this time the rate of growth was considerably slower than that of the control plants. The plants had become stunted and the leaves appeared to be narrower than normal with the lower ones curled slightly downwards and inwards. At the end of the season no influence on flower formation was observed. No shedding of leaves took place.

No Boron

The First Symptoms of deficiency were observed within 20 days and they were again more pronounced on the Harrison. There was a loss of colour and leaves became yellowish green in hue. Bronze spots similar to those on plants deprived of calcium appeared on both Rose and Bronze Harrison but not on Imperial. After that, however, Bronze Harrison showed no further symptoms. There was no effect whatever on the growth, the plant was perfectly normal until the end of the season and normal flowers were produced. The only difference between the treated plants and the control ones was the yellowish colour of the leaves and some interveinal mottling in the case of the former. On the other hand Imperial soon ceased to grow. The top leaves remained very small and turned yellow, acquiring almost a greyish appearance. At the end of the season small buds appeared but soon turned grey and then brown in colour and died without opening. The plant was very much stunted and the leaves, packed close together especially on the top of the plant, were in shape rather shorter and wider than those of the controls thus giving the impression that they are less deeply indented.

No Iron

No effect on growth was observed and it was only very late in the season, the beginning of November, that a little chlorosis of the top leaves became noticeable. Flowers were developed normally and at the same time as on the controlled plants though perhaps their stems were a little more slender.

No Manganese

This deficiency had no effect on growth or on flower formation. There was some intervenal chlorosis on the upper leaves and at the end of the season small circular spots of dead tissue slightly brown in colour were noticed when the leaves were examined against the light.

Solanum capsicastrum

No Calcium

The first symptoms were noticed on the 30th day. They were a general loss of colour, particularly noticeable at the top of the plant, and a slight yellowing of the tips of the young leaves. Subsequently the tips turned brown and typical scorching appeared No further growth took place after this. At the end of a further three weeks the plant was appreciably stunted and the young foliage was a very pale green, with the tips of the leaves still paler, almost white in colour. All shoots were affected, the growing tips being brown in colour and dying back and the youngest leaves being brown and dead. No growth of any side buds was observed. The old leaves were dark green in colour. The affected foliage showed no tendency to fall off. Only a few flowers appeared and only one of these set fruit.

When the roots were examined in mid December they were found to be poorly developed, dark brown in colour and showing some signs of dying back. There were very few fine roots.

No Magnesium

The first slight loss of colour, mainly in the middle leaves was noticed after five weeks. The lighter green colour appeared first at the base of a leaf, then interveinally while the apex remained green longer than the remainder. In some older leaves necrosis of the mid rib was one of the first things to be noticed and these leaves were usually the first to fall off. Once the symptoms appeared in a leaf necrosis of the affected parts followed, and when the parts which had remained green longest were examined against the light they showed small centres of necrosis. All the dead tissue was light brown in colour. At this stage the growth of the plant was only slightly affected.

After nine weeks treatment the plant turned suddenly yellow and lost practically all its foliage in a week, only a few of the youngest leaves remained. No more growth took place and some dying back of the youngest shoots occurred. A considerable number of flowers appeared but they were the first to fall off and only one fruit was set. The root system appeared to be quite normal and had a good colour.

No Boron

In this case two separate experiments were carried out. The first started on July 10th with plants about four months old which had been grown for a long time in sand using complete nutrients, and which were then changed over to a no boron solution. The second experiment was carried out with young plants which were about seven weeks old and which were transferred, after very careful watering of the roots, from soil to sand on the 11th August, after which they were watered with a no boron solution.

The results of these experiments differed slightly, but not in any unexpected way, and in general agreed very well together.

First Experiment

Symptoms

(*a*) Top leaves becoming paler and yellowish green intervenally.
(*b*) No further growth.
(*c*) Some of the side buds start to grow but only produce rosettes of small pale leaves which make the plant look curly with a number of small leaves on the top.
(*d*) Bright yellow lesions which afterwards turn brown appear near to the top of most shoots. A slow process of dying back takes place.
(*e*) Smallest top leaves turn brown, die, and remain on the top of dead brown shoot.
(*f*) Some of the leaves on the lower parts of the plant show necrosis of the mid rib which turns brown. The whole leaf then turns rapidly yellow from the middle outwards and falls off. The oldest leaves remain green and apparently unaffected.

Second Experiment

Symptoms

(*a*) There is a loss of colour in the leaves which become yellowish green. This is most pronounced in the top leaves but all the foliage is more or less affected. The whole of each leaf is affected and there is no mottling.

(*b*) No further growth.
(*c*) No similarity with the first experiment.
(*d*) Similar lesions to those in Experiment 1 but the dying back process was much quicker. All shoots were affected.
(*e*) The same effect as in Experiment 1.
(*f*) The same effect as in Experiment 1 but to a much greater extent. In a very short time plants have only a few older green leaves and some dead brown ones on the tops of dying shoots.

At this point one of the plants in the second experiment was changed over to a " complete " solution.

The roots of one plant in the first experiment and one in the second experiment were examined. They were poorly developed and brown in colour. They had very little fine roots and the ends of the main roots were branched with dark brown dead growing tips.

It was some time before the recovery of the third plant was noticeable. Both top and roots, however, made a very good recovery by growing side shoots. The new growth of roots was clean and white in colour with healthy root hairs. The old affected roots still remained brownish in colour with dark brown ends. It was only in a very few cases that the new growth seemed to be the continuation of the old one though this did happen in some less affected side roots. Omission of manganese or iron has not shown any visual signs of deficiency, growth being in both cases apparently quite normal. The roots were as good as or even better than those in the " complete " solution.

Tomatoes

In earlier reports the effects of deficiencies have been described on plants which were propagated and well established in complete nutrient. Under these conditions the first deficiency to be effective is calcium. This is followed by boron and much later the effects of the omission of magnesium are shown.

This year an attempt was made to determine whether these relative effects would be the same when the respective deficiencies were operating much earlier.

Accordingly a small number of tomato plants were raised in pure sand, distilled water being used for watering. Ailsa Craig was the variety used and the seeds were sown on the 11th June, the first seedlings appearing on the 21st June. The first feed solution contained N.P.K. only. On the 16th July the plants were re-potted in separate pots and the complete nutrient solution minus the respective elements calcium and magnesium was given and was used in the same way from this time onwards. Two plants were used for each treatment and for control purposes four plants were fed with complete nutrient solution.

The first symptoms appeared in plants treated with the solution containing no Magnesium on the 21st July. The plants were a much lighter green in colour and growth had ceased completely. In the next two or three days tip, marginal and in some cases interveinal scorching took place, the tissue becoming dry, and light brown in colour. On the 26th July the plants can be described as dying. On the 28th July, when most of the leaves were dead and the rest badly affected, this treatment was changed over to the complete nutrient solution. Recovery became evident from the 1st August onwards and some plants resumed their normal growth. No injury of any kind was observed on newly formed leaves. It was, however, some time before the plants regained a good colour.

The next pair of plants to show deficiency symptoms were those deprived of calcium. On the 26th July one plant had reached the stage of six pairs of leaves and the upper leaves showed a slightly paler colour with a slight mottling on the uppermost pair. The next day, July 27th, the yellowish brown spots appeared on the same pair. On July 28th the second plant showed the same symptoms and it was also noticed that the growing tip of the first plant was already dead. On this same day, namely the 28th July, the no calcium treatment was changed to the complete solution. Signs of recovery were noticeable in two days' time. The plant with the dead growing tip recovered by growing side shoots while the other plant resumed its normal growth. It must be mentioned, however, that in both cases all the new leaves showed signs of injury generally either in the complete lack or the severe malformation of the apical leaflet. Some of the other leaflets were also affected, the severity of the affection varying in direct proportion to the distance of the leaflet from the stem. It was four to six weeks before the new leaves developed normally again.

On the 3rd August the first symptoms of deficiency were noticed in plants treated with the no boron solution. The whole plant began to show slightly paler colour and there was a certain curling inwards of the older leaves. On the 9th August, when the above symptoms were quite evident, a slight violet discoloration appeared on the under surfaces of the lower affected leaves. At the same

time these leaves turned yellow developing this colour first along the mid rib and edges, the apex and basual part of the leaflet being the parts which remained green the longest. Extreme brittleness of the petioles or leaf stems and of the mid ribs was observed. Plants were distinctly stunted and the leaves shorter and wider than normal. The colour of the whole plant became much lighter and brighter, almost yellowish green in hue. Later the colour of the plant was a mixture of yellowish green and yellow with a good deal of purple, the later shade being especially evident on the lower leaves.

Very slow growth took place and when, between the 10th and 20th September, the growing tips finally died the plants had just reached the stage of the second truss of flowers, whereas the control plants were setting the fifth truss. The trusses were very small and the flowers did not open properly. The flower stalks turned yellow and most of the flowers fell off. Only one small fruit was set.

The growing tip and the uppermost pair of leaves which were very small turned yellow and then ash grey soon afterwards, while the pair of leaves immediately below which were also very small and malformed, appeared covered with brown spots scattered all over the surface. At the same time the top of the plant bent over to one side.

After some time some side shoots, especially on the lower part of the plant, started to grow. Most of the leaves were malformed, and after two or three weeks the growing tip died in the same way as the main one had done. After that the whole of the leaves, the petioles, and even the main stem which was dying back, turned rapidly to bright yellow.

It would thus appear that the incidence of symptoms due to these deficiencies depend on the time of the life of the plant at which the respective deficiencies become operative.

The effects on roots

The condition of some of the roots where boron and calcium had been omitted was considered to be sufficiently interesting to warrant examination. Our colleague Miss Ebben kindly carried out the examinations for us and reports as follows.

Boron deficiency

In the epidermal and cortical tissues the cell walls were slightly thicker than in normal roots.

The xylem was reduced in proportion to cortical tissue. The amount of xylem in boron deficient *Solanum capsicastrum* roots where secondary thickening had begun was less than in normal roots of a smaller diameter which had no secondary thickening. Some of the xylem vessels appeared to be blocked.

The amount of phloem did not seem to be affected by boron deficiency.

Calcium deficiency

The epidermal tissue was thicker walled than in normal roots.

The development of vascular tissue appeared normal although some blocking of the xylem vessels was observed. In many of the cortical cells there were deeply stained oval bodies, some of which appeared to be dividing. These were probably spore bodies of one of the Chytridiales and may have been responsible for the browning of the roots in the calcium deficient plants.

Various *Fusaria* were isolated from the boron and calcium deficient roots and from normal roots. No signs of fungal penetration were seen in the stained sections and the infection was probably only superficial and not responsible for the necrosis of the roots.

Summary

The fern *Asparagus plumosus nanus* is very susceptible to deficiencies of calcium, boron and magnesium respectively, even when the plants have been raised and grown for some time in a complete nutrient. Omission of calcium or boron results in the death of new shoots at the base and it is possible to differentiate between the effects of these two deficiencies at this stage. Apart from other symptoms a characteristic feature of magnesium deficiency is the shedding of needles.

Experiments with three varieties of indoor chrysanthemums show that there exists a varietal susceptibility to deficiencies. For plants established in a complete nutrient the omission of boron or calcium causes the most serious effects.

In *Solanum capsicastrum* omission of calcium, boron or magnesium causes serious ill-effects. Magnesium deficiency causes among other things almost complete shedding of leaves.

In tomatoes the effects of deficiencies appear to be related to the time from which the deficiency operates. For instance, when different elements are withheld from plants established on a complete nutrient the omission of calcium is evident before and more pronounced than that of magnesium.

On the other hand, if seeds are sown and the resulting seedlings grown in a nutrient from which an element is omitted the effects of magnesium deficiency are apparent before those of calcium deficiency.

In none of the experiments described here has the omission of iron or manganese any pronounced effect.

For all these experiments the basic solution was a modification of that recommended in Jealott's Hill Research Station Bulletin No. 2, together with the Hoagland A-Z solution. So far as they were available chemicals of Analytical Reagent quality were used and solutions made up in distilled water. The basic solution was modified where necessary in accordance with our experience of the subject under observation.

5. THE OCCURRENCE AND CORRECTION OF MAGNESIUM DEFICIENCY IN *SOLANUM CAPSICASTRUM* UNDER COMMERCIAL CONDITIONS

O. OWEN

A disorder of *S. capsicastrum* due to a deficiency of magnesium is described. The condition can be corrected by the addition of Epsom Salts to the fertilizers used.

In peace time *S. capsicastrum* is grown fairly extensively for decorative purposes during the winter months and particularly for the Christmas market. The aim is to produce a dark green background of foliage for the bright red berries. Usually they are at their best during December.

Before the war it sometimes happened that some growers failed to induce as good a colour as was desirable in the foliage and this was attributed to a mild deficiency of nitrogen. The condition was probably becoming increasingly common but was not considered to be serious and so far as can be ascertained has never been investigated. This is probably due to the fact that very few, if any, growers regarded this as a major crop, although the present writer recalls a grower of many crops on a big scale saying he " would give anything " to maintain a dark green colour in his Solanums.

During the post-war years the cultivation of this plant has been resumed generally and in 1946 we were consulted by a grower about the state of his crop which was far from satisfactory. Seeds had been sown in a mixture of baked soil and spent hops during the first week in January. Seedlings were pricked out at the end of February into a mixture of baked soil, peat and sand plus about 3 per cent. of bone meal. They were potted into John Innes potting compost in thumbs during April and finally into large 60's at the end of May and the beginning of June. From the middle of July until the end of September when the plants were brought in under glass they were fed with a " complete " fertilizer every two or three weeks according to the rate of growth. In the main this was the system which had been used for many years before the war.

That all was not well with some of the plants became evident during August when they were showing a good deal of blossom and fruit had begun to set, in that they showed some lack of colour. This was by no means general but was confined to odd plants. Later the condition spread rapidly and by the end of September the majority of plants had lost the characteristic deep green colour. Concurrently on many of the older leaves pale green areas appeared interveinally and later these became yellow. At this stage the veins remained green as did the tips on many of the leaves, and the condition was reminiscent of magnesium deficiency on tomatoes. From this stage the condition of the plants deteriorated steadily, so that by the beginning of December there were more yellow leaves than green ones. In addition the veins lost most of the colour and at this period many plants lost most of their foliage and as a result were quite unmarketable.

Comparative tissue tests carried out on whole leaves confirmed the view that the condition was due to magnesium deficiency and attempts were made immediately to correct it.

In view of the success which has attended the use of the spray treatment already recommended by us [1] and later by Nicholas [2] for magnesium deficiency in tomatoes, this treatment was tried on a batch of about a hundred plants. The spray was the standard 2 per cent. Epsom Salts with Estol H as wetter, and it was applied when the condition was developing fairly rapidly. Examination of the plants ten days later showed that there had been little effect on the development of the condition. Although the spraying had been carried out on a dull day there was no sign of injury to blooms or foliage. On the assumption that the solution may not have been strong enough another batch of plants was treated with a 4 per cent. solution of Epsom Salts with Estol H. Examination a week later showed that although the development of the deficiency symptoms had been arrested somewhat there was some damage to blossoms and to some leaves at the axils, and this was sufficient to rule out the possibility of using the higher strength even if it did correct the deficiency. This

suggested that owing to the differences in leaf structure and in the habit of the plant as compared with the tomato magnesium was not being absorbed as hoped and would, therefore, not give the results for which we hoped.

It should be remarked here that when the plants were sprayed they were packed fairly closely together and there was the possibility that an appreciable amount of the spray had fallen on to the surface of the soil in the pots, and the limited correction observed might be due to absorption of magnesium via the roots. Estimation of magnesium by Rice Williams's method [3] in the top inch of soil from treated and untreated pots respectively showed that in the former the content was some 20 per cent. higher.

By this time it was too late to hope for any improvement in that particular crop but it may be recorded that of an original batch of ten thousand plants few were of first quality and by Christmas week of those unsold practically all had lost their foliage.

For the 1947 crop it was decided to concentrate on testing out the effect of adding Epsom Salts to the potting mixtures. At the same time another series of experiments was planned at another centre to determine the importance of the actual time of application. In view of previous experience of the uncertain effects of the addition of Epsom Salts in tomato borders and having regard to the fact that *S. capsicastrum* is watered heavily during the summer months it was decided to use fairly heavy applications. Accordingly it was decided to use at any stage an amount of Epsom Salts equal to the sulphate of potash used at that stage and, in the case of " complete " mixtures, an amount equal to twice the potash (K_2O) applied in the mixtures. On the face of it this appears somewhat drastic but our experience has been with most crops that the effect of an excess of magnesium induces a dark colour in the foliage and we were assured that the foliage of *S. capsicastrum* could not be too dark.

The results of the " timing " experiment may be summarized as follows :—

(*a*) The most effective treatment is that in which Epsom Salts is used at all stages of growth after pricking off. Under those conditions excellent plants resulted. In 60's all the foliage remained a good dark green colour and there were between 35 and 50 berries on each plant at Christmas time. A few plants in 48's were kept in an ordinary dwelling house and the foliage retained its colour until the following April by which time many berries had fallen off and those remaining were wrinkled and shrunken.

(*b*) Treatment with Epsom Salts until fruit sets does not give as food results as under (*a*) in that some of the plants lost colour in November and December.

(*c*) Treatment after the signs of the deficiency have developed has only a limited effect on the condition.

On the commercial scale the treatment was completely successful. Some twelve thousand plants were raised and not more than a dozen lost colour up to Christmas. Some retained maintained a good colour in a dwelling house until the end of March. Twenty plants from the same sowing which received the same fertilizer treatment but without the Epsom Salts were kept as controls. Of these all had lost most of the foliage by the middle of December.

It so happened that 1947 was a good year and plants grew rapidly while out of doors during the summer. Consequently it was desirable to top dress them every fourteen to sixteen days. The first feed was applied July 1st-4th. This and the next dressing consisted of a mixture containing 5·5 per cent. N, 8·5 per cent. P_2O_5, 6 per cent. K_2O. One pound Epsom Salts was added to eight pounds of this mixture. Subsequent dressings consisted of a mixture containing 10·5 per cent. N, 5·5 per cent. P_2O_5, 4·5 per cent. K_2O. One pound Epsom Salts was added to eleven pounds of this mixture. All the top dressing was done by hand and it is not possible to state the exact amounts used but it was estimated that each pot received one-sixth of an ounce of mixture at each application. The final dressing was applied September 24th-26th.

For the 1948 crop the same procedure was followed and the results were substantially the same as those already recorded for 1947. Plants did not grow so quickly during the season and top dressing every three weeks was adequate.

The recommended treatment then, consists of adding the same amount of Epsom Salts as of sulphate of potash used. At any stage where a mixed fertilizer is applied, the Epsom Salts added should be approximately equal to twice the amount of potash (K_2O) applied in the fertilizer. Where a sufficient number of plants are grown to make it worth while it is suggested that the fertilizer supplier be asked to make up the complete mixture ready for use.

References

[1] Owen, O., Rep. Exp. Res. Sta. Cheshunt, 1944, 30, 65.

[2] Nicholas, D. J. D., *J. Hort. Sci.*, 1928, 24, 1.

[3] Williams, R., *J. Agr. Sci.*, 1928, 18, 439.

APPENDIX "A"

PUBLICATIONS

1919

PAINE, S. G., and BEWLEY, W. F. Studies in Bacteriosis IV. "Stripe" Disease of Tomato. Ann. Appl. Biol., VI, 183–202.

1920

BEWLEY, W. F. "Damping-off" and "Foot-rot" of Tomato Seedlings. Ann. Appl. Biol., VII, 156–172. (Abridged account J. Minist. Agric. XXVII, 670–673.)
LLOYD, Ll. The Habits of the Glasshouse Tomato Moth, *Hadena* (Polia) *oleracea* and its Control. Ann. Appl. Biol., VII, 10–19.
PAINE, S. G., and BEWLEY, W. F. "Stripe" Disease of the Tomato. J. Minist. Agric., XXVI, 998–1000.

1921

BEWLEY, W. F. Control of "Damping-off" and "Foot-rot" of Tomatoes. J. Minist. Agric., XXVIII, 653–654.
———— and BUDDIN, W. On the Fungus Flora of Glasshouse Water Supplies in Relation to Plant Disease. Ann. Appl. Biol., VIII, 10–19.

1922

BEWLEY, W. F. "Sleepy Disease" of the Tomato. Ann. Appl. Biol., IX, 116–134.
———— Anthracnose of the Cucumber under Glass. J. Minist. Agric., XXIX, 469–472, and 558–562.
———— "Tomato Diseases." J. R. Hort. Soc., XLVII, 169–174.
LLOYD, Ll. The Control of the Greenhouse White Fly, with notes on its biology. Ann. Appl. Biol., IX, 1–34.

1923

BEWLEY, W. F. Disease of Glasshouse Plants. 208 pp. (Benn, Lond.)
———— "Sleepy Disease" of the Tomato. J. Minist. Agric., XXX, 450–457.
OWEN, O. Carbon Dioxide in relation to Glasshouse Crops. Part 1. Ann. Appl. Biol., X, 312–317.
———— and WILLIAMS, P. H.. Carbon Dioxide in Relation to Glasshouse Crops, Part II. Ann. Appl. Biol., X, 318–325.
PAINE, S. G., and BEWLEY, W. F. Further Investigations of the "Stripe" Disease of Tomato. Ann. Appl. Biol., X, 89–95.
SPEYER, E. R. Mycetophilid Flies as Pests of the Cucumber Plant in Glasshouses. Bull. Ent. Res., XIII, 255–259.

1924

BEWLEY, W. F., and SHEARN, J. A Root Disease of the Tomato caused by *Colletotrichum tabificum* (Hallier *pro parte*) Pethybridge. Ann. Appl. Biol., XI, 244–251.
SPEYER, E. R., and OWEN, O. The Action of some Organic Compounds upon the Cucumber House Woodlouse. Ann. Appl. Biol., XI, 236–243.

1926

BEWLEY, W. F. Practical Soil Sterilisation by Heat for Glasshouse Crops. J. Minist. of Agric., XXXIII, 297–311.
———— Note on the Preservation of Plate Cultures of Fungi. Ann. Appl. Biol., XIII, 577–579.
———— Diseases of Glasshouse Plant. Essex Farmers' J. V. Parts 1 and 2.
———— and WHITE, H. L. Some Nutritional Disorders of the Tomato. Ann. Appl. Biol., XIII, 323–338.
OWEN, O., SMALL, T. and WILLIAMS, P. H. Carbon Dioxide in Relation to Glasshouse Crops. Part III. Ann. Appl. Biol., XIII, 560–576.
SPEYER, E. R., and OWEN, O. The Fumigation of Tomato Houses with Hydrocyanic Acid Gas. Ann. Appl. Biol., XIII, 144–147.

1927

SPEYER, E. R. An important Parasite of the Greenhouse White Fly (*Trialeurodes vaporariorum*, Westwood). Bull. Ent. Res., XVII, 301–308.
SMALL, T. Rhizoctonia "Foot-rot" of the Tomato. Ann. Appl. Biol., XIV, 290–295.

1928

SMALL, T. A. Disease of the Strawberry Plant. J. Pomol., VII, 212–215.
SPEYER, E. R. The Red Spider Mite (*Tetrynchus Telarius*, L.). J. Pomol., VII, 161–171.

1929

BEWLEY, W. F. The Effect of Environmental Conditions on Plant Diseases under Glass. Ann. Appl. Biol., XVI, 190–192.
———— The Influence of Bright Sunshine upon the Tomato under Glass. Ann. Appl. Biol., XVI, 281–7.
———— The Practical Sterilisation by Heat of Small Quantities of Soil. J. Minist. Agric., XXXVI, 623–634.

OWEN, O. The Occurrence of Chlorates in a Tomato Soil. J. Pomol., VII, 270–275.
———— The Effect of Copper Sulphate on Tomato Plants. Ann. Appl. Biol., XVI, 430–437.
———— The Analysis of Tomato Plants, Part I. J. Agric. Sci., XIX, 413–432.
SMALL, T. Temperature and Humidity in relation to Tomato Leaf Mould. Ann. Appl. Biol., XVI, 192–193.
SPEYER, E. R. The Greenhouse White Fly. J. R. Hort. Soc., LIV, 181–192.
WHITE, H. L. The Wilt Disease of the Carnation. J. Pomol., VII, 303–323.

1930

BEWLEY, W. F. Some Experiments on the Heating of Glasshouse Soil by Electricity. Rep. and Proc., IXth Internat. Hort. Congress, London.
———— and BOLAS, B. D. Aucuba or Yellow Mosaic of the Tomato Plant: Reaction of Infected Juice. Nature, CXXV, 130.
———— and CORBETT, W. The "Maturation Period" of the Tomato Plant. Ann. Appl. Biol., XVII, 267–279.
———— and ———— The Control of Cucumber and Tomato Mosaic Diseases in Glasshouses by the use of Clean Seed. Ann. Appl. Biol., XVII, 260–266.

1930

BOLAS, B. D., and BEWLEY, W. F. Aucuba or Yellow Mosaic of Tomato; A Note on Metabolism. Nature, CXXVI (3178), 471.
JOZEFOWICZ, MARY. The Effect of certain Treatments on the Germination of Tomato Seeds. Ann. Appl. Biol., XVII, 504–513.
———— Some Observations on Tomato Plants from Seed submitted to High Temperatures. Ann. Appl. Biol., XVII, 514–521.
SMALL, T. The Relation of Atmospheric Temperature and Humidity to Tomato Leaf Mould (*Cladosporium fulvum*). Ann. Appl. Biol., XVII, 71–80.
— — and WHITE, H. L. Carbon Dioxide in Relation to Glasshouse Crops, Part IV. Ann. Appl. Biol., XVII, 81–89.
WHITE, H. L. Carbon Dioxide in relation to Glasshouse Plants, Part V. Ann. Appl. Biol., XVII, 755–766.

1931

BEWLEY, W. F. The Nature of the Virds Principle in Mosaic Disease. Nature, CXXVII, 442.
———— Practical Soil Sterilisation with special reference to Glasshouse Crops. Bull. Minist. Agric., No. 22.
OWEN, O. The Analysis of Tomato Plants: Part II, The Effect of Manurial Treatment on the Composition of Tomato Foliage. J. Agric. Sci., XXI, 442–451.
SMALL, T. Experiments on the Control of Tomato Leaf Mould (*Cladosporium fulvum*) by Fungicides and Fumigants. Ann. Appl. Biol., XVIII, 305–312.

1932

BEWLEY, W. F. Some recent developments in relation to Glasshouse Crops. H.E.A. Year Book, I, 23–26.
———— and ORCHARD, O. B. The Control of Tomato Leaf Mould. Ann. Appl. Biol., XIX, 185–189.
READ, W. H. The Toxicity of the Vapours of Volatile Organic Compounds to the "Red Spider" Mite (*Tetranychus telarius* L.). Ann. Appl. Biol., XIX, 342–438.

1933

AINSWORTH, G. C. An Investigation of Tomato Virus Diseases of the Mosaic "Stripe" Streak Group. Ann. Appl. Biol., XX, 421–428.
BOLAS, B. D., and MELVILLE, R. The Influence of Environment on the Growth and Metabolism of the Tomato Plant. I. Methods, Technique and Preliminary Results. Ann. Bot., Lond., XLVII, 673–688.
READ, W. H., and ORCHARD, O. B. Plant Injury following the Burning of Sulphur in Empty Glasshouses. J. Minist. Agric., XXXIX, 1085–1086.
SECRETT, F. A., and BEWLEY, W. F. Cultivation of Lettuce for Market, Pamp. issued by R. Hort. Soc.

1934

AINSWORTH, G. C., BERKELEY, G. H., and CALDWELL, J. A comparison of English and Canadian Tomato Virus Diseases. Ann. Appl. Biol., XXI, 566–580.
———— A Comparison of certain English and Canadian Potato Viruses found infecting Tomatoes. Ann. Appl. Biol., XXI, 581–587.

1934

BEWLEY, W. F. Health and Disease in Plants. J. R. Hort. Soc., LIX, 386–396.
———— Some Physiological Disorders of Glasshouse Crops. Ann. Appl. Biol., XXI, 319–322.
———— Raising the Soil Temperatures in Glasshouses. J. Minist. Agric., XL, 1047–1056.
———— Tomatoes: Cultivation, Diseases and Pests. Bull. Minist. Agric., No. 77, 71 pp.
———— and HARNETT, J. The Cultivation of Mushrooms. 63 pp. (Anglo-Scottish Press, London.)
SPEYER, E. R. Some Common Species of the genus *Thrips* (Thysanoptera). Ann. Appl. Biol., XXI, 120–152.

1935

AINSWORTH, G. C. Spotted Wilt of Richardias (Arums). Gardeners' Chron., XCVII (2507), 31.
———— Mosaic Diseases of Cucumber. Ann. Appl. Biol., XXII, 55–67.
— — Virus Diseases of the Cucumber. J. Minist. Agric., XLII, 338–344.
———— Another new Virus Diseases of the Tomato. Gardeners' Chron., XCVIII, 320–321.
———— Fig. Mosaic. J. R. Hort. Soc., LX, 532–533.

BEWLEY, W. F. Cheshunt Early Giant Lettuce; a new forcing type. J. Minist. Agric., XLII, 45–47.
BOLAS, B. D., and MELVILLE, R. The Effect on the Tomato Plant of Carbon Dioxide produced by Combustion. Ann. Appl. Biol., XXII, 1–15.
———— and SELMAN, I. W. An inexpensive recording Porometer. Ann. Bot., Lond., XLIX, 803–808.

1936

AINSWORTH, G. C. Detection of Spotted Wilt in Chrysanthemums. Nature, Lond., CXXXVII, 868.
———— "Bushy Stunt": a Virus Disease of the Tomato. J. Minist. Agric., XLIII, 266–269.
———— and SELMAN, I. W. Some Effects of Tobacco Mosaic Virus on the Growth of Seedling Tomato Plants. Ann. Appl. Biol., XXIII, 89–98.
BEWLEY, W. F. Tomato Production for High Quality Fruit. Misc. Pub., No. 1, Exp. Sta. Cheshunt, pages 1–20.
SPEYER, E. R. Injury to Carnation Flowers caused by Thrips. Carnation Year Book, 14–18, Figs. 1–6.
WHITE, H. L. On Verticillium Wilt of the Perpetual-flowering Carnation. J. Pomol., XIV, 216–226.
———— Anther Smut of the Perpetual-flowering Carnation. Gardeners' Chron., C. 254.
WILLIAMS, P. H. A new Eelworm Disease of the Tomato. Gardeners' Chron., XCIX, 316.
———— A Disease of Mushrooms new to Great Britain. Gardeners' Chron., C. (2591), 147.
———— Some important Diseases of Glasshouse Plants. Ann. Appl. Biol., XXIII, No. 1, 189–192.

1937

AINSWORTH, G. C. The Plant Diseases of Great Britain: A Bibliography, pp. XII W L. 273 (Chapman & Hall, Ltd., London).
———— "Enation Mosaic" of Tomato caused by a virus of the *tobacco virus* 1 type. Ann. Appl. Biol., XXIV, 545–556.
———— OYLER, E., and READ, W. H. The Spotting of Tomato Fruit by *Botrytis*. Gardeners' Chron., CII (2656). 380–381.
BEWLEY, W. F., HARNET, J., and WILLIAMS, P. H. The Control of White Plaster Mould (*Oospora fimicola*) on Mushroom Beds. Gardeners' Chron., CII (2642), 130.
OWEN, O. Note on the Use of Chlorate Weed-killers. J. Minist. Agric., XLIV, 866–869.
OYLER, E., and BEWLEY, W. F. A Disease of Cultivated Heaths caused by *Phytophthora Cinnamoni* Rands. Ann. Appl. Biol., XXLV, 1–16.
MELVILLE, R. The Influence of Environment on the Growth and Metabolism of the Tomato Plant. II, The Relationship between Water Content and Assimilation. Ann. Bot., Lond. N.S.I., 153–174.

1938

AINSWORTH, G. C. A Note on certain Viruses of the *Cucumber virus* 1 type isolated from monocotyledonous Plants. Ann. Appl. Biol., XXV (4), 867–869.
—— OYLER, ENID, and READ, W. H. Observation on the Spotting of Tomato Fruits by *Botrytis cinerea* Pers. Ann. Appl. Biol., XXV (2), 308–331.
BEWLEY, W. F. Recent Work on Rose Disease, Sci. Hort. VI, 97–101.
———— and HARNET, J. The Cultivation of Mushrooms. Revised and enlarged edition, p. 95. (Anglo-Scottish Press, Ltd.).
OWEN, O. V. Chlorate Weed-killers. Ann. Appl. Biol., XXV (3), 659–660.
SPEYER, E. R. The Carnation Tortrix. Carnation Year Book, 21–30, Figs. 1–9.
———— Pests of the Carnation and their Control. Sci. Hort., Vol. VI, 72–84, Figs. 20–21.
WHITE, H. L. Stem-Rot and Wilt of the Perpetual-flowering Carnation. Sci. Hort., VI, 86–92.
———— Observations of the Effect of Nitrogen and Potassium on the Fruiting of the Tomato. Ann. Appl. Biol., XXV, 20–49.
———— Further Observations of the Incidence of Blotchy Ripening of the Tomato. XXV, 544–557.
———— The Anther Smut Disease of the Perpetual-flowering Carnation. British Carnation Soc. Year Book, 40–43.
———— The Sterilisation of Lettuce Seed. Ann. Appl. Biol., XXV, 767–780.
WILLIAMS, P. H. Investigation on the Rust of Roses *Phragmidium mucronatum* Fr. Ann. Appl. Biol., XXV (4), 730–741.
BOLAS, B. D., MELVILLE, R., and SELMAN, I. W. The Measurement of Assimilation and Translocation in Tomato Seedlings under the conditions of Glasshouse Culture. Ann. Bot., London., N.S. II, 717–728.

1939

AINSWORTH, G. C. The Nomenclature of Plant Viruses. Chron. Bot. V, 193–194.
———— and OGILVIE, L. Lettuce Mosaic. Ann. Appl. Biol., XXVI (2), 279–297.
SPEYER, E. R., and READ, W. Red Spider-Mite (*Tetranychus telarius* L.). Carnation Year Book, 6–16, Figs. 1–12.
WILLIAMS, P. H. A Mushroom Disease caused by *Mycogone rosea*. Gardeners' Chron., CV. 2, 729, p. 236.

1940

AINSWORTH, G. C. The Identification of certain Viruses found infecting Leguminous Plants in Great Britain. Ann. Appl. Biol., XXVIII, 218–226.
GOODALL, D. W., and BOLAS, B. D. Vernalisation of Tomatoes. Gardeners' Chron., CVIII, 261–262. Reprinted in Fruitgrower XCI 27 (1941).

1941

PARR, W. J., and SPEYER, E. R. Some Observations on the Life History of the Angle Shades Moth (*Brotolomia Meticulosa* L.). Ann. Appl. Biol., XXVIII, No. 1, pp. 29–33.
SELMAN, I. W. Control of Plant Virus Diseases by Cultural Methods. Nature (London), 147, 181–182.
———— Spotted Wilt Diseases of Tomatoes. Gardeners' Chron., CIX, 241–242.
———— The Effects of certain Mosaic-inducing Viruses on the Tomato Crop under Glass. Journ. Pom. & Hort. Sci., XIX, 107–136.
SPEYER, E. R., and PARR, W. J. The External Structure of some Thysanopterous Larvæ. Trans. R. Ent. Soc., Lond., Vol. 91, Part 2, pp. 559–635.

1942

SELMAN, I. W. The Relation between Mosaic Infection and Yield Reduction in Glasshouse Tomatoes. Journ. Pom. & Hort. Sci., XX, 49–58.
OYLER, ENID, and READ, W. H. A Stem-Rot of Tomato caused by *Didymella lycopersici*. Gardeners' Chron. CXII, No. 2910, p. 121.
GOODALL, D. W., and BOLAS, B. D. Vernalisation of Tomato Seed. Ann. Appl. Biol., XXIX, 1–10.

1943

WILLIAMS, P. H., and SHEARD, ENID. Stem-Rot of Tomato caused by *Phytophthora parasitica*. Gardeners' Chron. CXIV, No. 2959, p. 96.
SELMAN, I. W. The Influence of Lime and Potash on Mosaic Infection in the Tomato (var. Potentate) under glass. J. Pom. XX, 89–106.
———— "The Appearance and Spread of Mosaic Infection in the Tomato Crop and the Relation to Seed, Transmission of the Virus." Ann. Appl. Biol., 30, 331–338.

1944

SELMAN, I. W. The Susceptibility of Lettuce to Mosaic Virus in Relation to Nitrogen Phosphate and Water Supply. J. Pom. XXI, 28–33.
———— Virus Infection and Water Loss in Tomato Foliage. J. Pom., XXI, 146–154.
GOODALL, D. W. Proportion of Leaves to Flower Trusses in the Tomato Plant. Gardeners' Chron., CXV, 39.

1945

SELMAN, I. W. Virus Infection and Water Loss in Tomato Foliage. J. Pom. & Hort. Sci., XXI, Nos. 1–4, pp. 146–154.

1946

OWEN, O. Use of Sodium Chlorate Weed-killer. Gardeners' Chron., CXX, p. 55.
SELMAN, I. W. The Localization of Tobacco Mosaic Virus in Tomato Fruits. J. Pom. & Hort. Sci., XXII, Nos. 3 and 4, pp. 226–230.

1947

OWEN, O. The Potash Content of Some Plant and Wood Ashes. Gardeners' Chron., Aug. 2nd, 1947.
READ, W. H. D.D.T. and Rose Pests. The Rose Annual (British Nat. Rose Soc.), 1947, pp. 44–50.

1948

READ, W. H. Insecticidal Smokes and Aerosols. Gardening Illustrated 1948, LXV, 128–156.
OWEN, O. Alginates Improve Soil Texture. The Grower, Vol. 29, No. 24, pp. 890–891.
GROSSBARD, E. Nature, 1948, Vol. 161, p. 614.
———— Gardening Illustrated 1948, LXV, 94.
———— Gardening Illustrated 1948, LXV, 116.
———— Gardening Illustrated 1948, LXV, 211.

APPENDIX "B"

MANURIAL TREATMENT IN TOMATO EXPERIMENTS

(Except plots in Appendix C)

			BASE TREATMENT						TOP DRESSING							
House	Plot	Sterilisation	Lime	Stable Manure	Hoof and Horn	Bone Meal	Sulphate of Potash	Sulphate of Ammonia	Sulphate of Potash with first Watering	Balanced Mixture	Dried Blood Mixture	Sulphate of Ammonia	Superphosphate	Sulphate of Potash	Dried Blood	Nutrient Feeding by Soln-feeder
1		Steam	1 ton per acre	15 tons per acre	10 cwts. per acre	10 cwts. per acre	10 cwts. per acre		5 cwts. per acre	6 applications	None					
3	1	Steam	1 ton per acre	15 tons per acre	10 cwts. per acre	10 cwts. per acre	10 cwts. per acre		5 cwts. per acre	6 applications	1 application					
	2	,,	,,	,,	,,	,,	,,		,,	,,						
	3	,,	,,	,,	,,	,,	,,		,,	,,						
	4	,,	,,	,,	,,	,,	,,		,,	None	None					5 applications
	5	,,	,,	,,	,,	,,	,,		,,	6 applications	,,					
	6	,,	,,	,,	,,	,,	,,		,,	,,	,,					
	7	,,	,,	,,	,,	,,	,,		,,	,,	,,					
	8	,,	,,	,,	,,	,,	,,		,,	None	,,					5 applications
4	4	Steam	1 ton per acre	None	10 cwts. per acre	10 cwts. per acre	10 cwts. per acre		5 cwts. per acre	6 applications	None					
	5	,,	,,	,,	,,	,,	,,		,,	,,	,,					
	6	,,	None	,,	,,	,,	,,		,,	,,	,,					
	7	,,	1 ton per acre	,,	,,	,,	,,		,,	,,	,,					
5	1	Steam	1 ton per acre	Treated Straw Peat	10 cwts. per acre	10 cwts. per acre	10 cwts. per acre		5 cwts. per acre	6 applications	2 applications					
	2	,,	,,	None	,,	,,	,,		,,	,,	,,					
	3	,,	None	None	,,	,,	,,		,,	,,	,,					
	4	,,	,,	,,	,,	,,	,,		,,	,,	,,					
	5	,,	,,	,,	,,	,,	,,		,,	,,	,,					
	6	,,	,,	,,	,,	,,	,,		,,	,,	,,					
	7	,,	1 ton per acre	,,	,,	,,	,,		,,	,,	,,					
	8	,,	,,	,,	,,	,,	,,		,,	,,	,,					
7	–	Steam	1 ton per acre	None	10 cwts. per acre	10 cwts. per acre	10 cwts. per acre		5 cwts. per acre	7 applications						
8	2	Steam	1 ton per acre	None	10 cwts. per acre	10 cwts. per acre	10 cwts. per acre		5 cwts.	None	None					6 applications
	4	,,	,,	,,	,,	,,	,,		,,	,,	,,					,,
	6	,,	,,	,,	,,	,,	,,		,,	,,	,,					,,
	8	,,	,,	,,	,,	,,	,,		,,	,,	,,					,,
	1	,,	,,	,,	,,	,,	,,		,,	6 applications	,,					
	3	,,	,,	,,	,,	,,	,,		,,	,,	,,					
	5	,,	,,	,,	,,	,,	,,		,,	,,	,,					
	7	,,	,,	,,	,,	,,	,,		,,	,,	,,					
9	1	Steam	1 ton per acre	None	None	10 cwts. per acre	10 cwts. per acre	10 cwts. per acre	5 cwts. per acre	None	None	5 cwts. per acre	10 cwts. per acre	10 cwts. per acre		
	2	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,		
	3	,,	,,	,,	10 cwts. per acre	,,	,,	None	,,	6 applications	,,					
	4	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,		
10		Steam	1 ton per acre	None	10 cwts. per acre	10 cwts. per acre	10 cwts. per acre	None	5 cwts. per acre	7 applications	1 application					
11	1	Steam	1 ton per acre	None	10 cwts. per acre	10 cwts. per acre	10 cwts. per acre	None	5 cwts. per acre	6 applications	2 applications					
	2	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,					
	3	,,	None	,,	,,	,,	,,	,,	,,	,,	,,					
	4	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,					
12	1	Steam	1 ton per acre	None	10 cwts. per acre	None	10 cwts. per acre	None	5 cwts.	None	None	None	None	5 cwts. per acre	10 cwts. per acre	
	2	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	
	3	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	
	4	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	
Rose House		Formal-dehyde	1 ton per acre	15 tons per acre	10 cwts. per acre	None	10 cwts. per acre	None	5 cwts. per acre	7 applications	1 application					

APPENDIX "C"

MANURES APPLIED IN PLOTS 1–3 AND 8–10 IN TOMATO HOUSE 4

Plot	Title	Base Manure in Lbs. per sq. yds.				*Top Dressing in Lbs. per sq. yds.		
		Lime	Stable Manure	Super-phos-phate	Sulphate of Potash	Super-phos-phate	Sulphate of Ammonia	Sulphate of Potash
1	Complete Artificials (I) less Nitrogen	1·0	—	0·4	0·1	0·5	—	0·2
2	Unmanured	1·0	—	—	—	—	—	—
3	Complete Artificials	1·0	—	0·4	0·1	0·5	0·2	0·2
8	Complete Artificials with Dung	1·0	7	0·4	0·1	0·5	0·2	0·2
9	Complete Artificials less Phosphate	1·0	—	—	0·1	—	0·2	0·2
10	Complete Artificials less Potash	1·0	—	0·4	—	0·5	0·2	—

* The Top-dressing was applied in eight equal instalments.

APPENDIX "D"

DATES OF CULTURAL OPERATIONS, 1948

Crop	Sown	Potted into 60's	Potted into 32's	Planted out in Borders	First top Dressing	First Fruit Picked	Last Feed Applied	Last Fruit Picked
Tomatoes	Jan. 6	Jan. 27	—	Mar. 3	May 8	May 22	July 29	Nov. 5
Cucumbers	Feb. 27	—	Mar. 12	Mar. 25	May 1	Apr. 22	July 24	Sept. 16

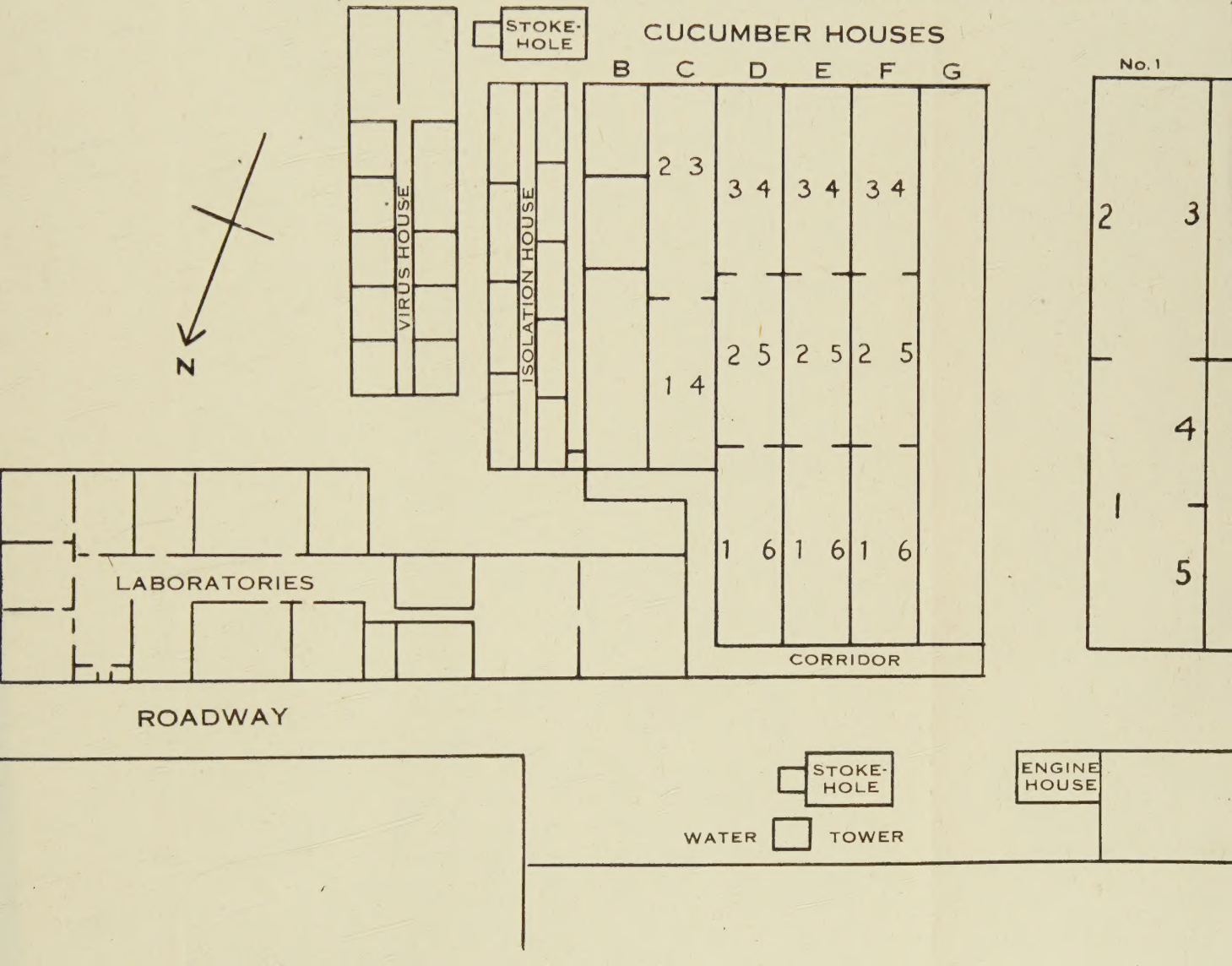
APPENDIX "E"

METEOROLOGICAL RECORDS, 1948

Month	Air Temperatures						Grass Temperatures			Rainfall				Mean Soil Temperatures		Hygrometer				Bright Sunshine		Barometer
	Mean		Absolute Maximum		Absolute Minimum		Av. Min.	Absolute Minimum		Total Precipitation	No. of Days Pptn.	Greatest Fall				Dry Bulb	Depres. of Wet Bulb	Relative Humidity %	Dew Point	Total No. of Hours	Daily Average	
	Max.	Min.	Temp.	Date	Temp.	Date		Temp.	Date			Amt.	Date	1 ft.	2 ft.							
	° F.	° F.	° F.		° F.		° F.	° F.		Ins.		Ins.		° F.	° F.	° F.	° F.		° F.			Ins.
JANUARY ...	47·9	36·6	57·0	4th	26·0	19th	—	—	—	3·95	21	0·56	10th	41·3	43·1	41·8	1·1	90·8	39·1	28·6	0·9	29·42
FEBRUARY ...	46·5	35·1	58·0	29th	21·0	19th, 21st	—	—	—	1·57	13	0·33	21st	40·3	42·1	41·7	2·0	82·7	36·7	73·0	2·5	30·09
MARCH ...	57·1	41·5	76·0	9th	30·0	23rd	35·2	26·0	23rd	0·83	4	0·46	31st	43·7	44·1	46·5	2·2	85·2	40·9	128·2	4·1	30·33
APRIL	61·1	40·4	73·0	21st	31·0	4th	35·9	26·0	11th	1·23	11	0·42	3rd	48·0	47·7	51·3	4·4	72·4	42·5	199·5	6·6	29·85
MAY	64·5	43·3	78·0	18th	30·0	2nd	40·0	27·0	2nd	2·37	13	0·63	29th	53·6	—	55·9	4·3	75·5	47·9	232·2	7·5	29·96
JUNE	68·2	50·0	81·0	15th	43·0	2nd	47·0	40·0	2nd	2·46	16	0·51	1st	58·9	—	59·4	4·7	73·7	50·6	152·0	5·1	29·92
JULY	73·2	53·1	94·0	29th, 30th	42·0	11th, 16th	49·2	36·0	16th	0·70	7	0·33	4th	59·3	—	63·2	4·5	75·5	55·0	173·2	5·6	29·98
AUGUST ...	71·3	51·3	81·0	1st	43·0	19th, 28th	47·7	40·0	19th	3·14	14	0·84	7th	59·3	—	62·1	3·2	81·7	56·2	125·9	4.1	29·83
SEPTEMBER ...	67·8	49·5	79·0	9th	32·0	21st	46·1	29·0	21st	1·55	8	0·81	12th	56·2	—	57·5	2·1	86·7	53·4	131·9	4·4	29·98
OCTOBER ...	57·8	41·0	72·0	2nd	24·0	26th	37·8	22·0	26th	1·79	9	0·41	25th	50·7	—	48·8	1·1	92·5	46·6	79·0	2·5	29·99
NOVEMBER ...	50·1	37·5	60·0	13th	24·0	25th	34·9	21·0	25th	2·14	11	0·61	6th	46·2	—	44·7	0·8	93·5	42·5	51·9	1·7	—
DECEMBER ...	48·8	38·2	57·0	6th, 7th, 14th	23·0	26th	35·0	19·0	26th	2·46	15	0·55	31st	43·4	—	43·1	1·2	91·1	41·0	37·9	1·2	—

Total Rain for Year: 24·19 inches. Number of Days Precipitation: 142. Total Bright Sunshine for Year: 1,413.3 hours.

DIAGRAM SHEWING ARRANGEMENT



OF EXPERIMENTAL PLOTS, 1948